Complex Climatology

Kompleksnaya Klimatologiya, Russian book, 1949

by

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Introduction

COMPLEX CLIMATOLOGY

Complex climatology can be said to have begun in about 1920-1925, when a number of works appeared in Soviet and foreign literature containing original methods for climatological processing of meteorological observations. The first of these were those by Ye. Ye. Fedorov in 1921 and 1925, Howe in 1925, Switzer in 1925, and Nichols in 1925. But despite the fact that these works were published almost simultaneously, the last were more or less three consecutive stages of development of the same idea. Undoubtedly, the works of Ye. Ye. Fedorov were the most fruitful and advanced and he should be credited with creating the school of complex climatology.

Recently, complex climatology has been developed in many directions both by the works of Ye. Ye. Fedorov and his students (A. I. Baranov, N. N. Calakhov, A. P. Gal'tsov, L. Y. Klimenko, S. A. Maksimov, Ya. I. Fel'dman, L. A. Chubukov, and a number of others). Consequently, it is a school of climatological thought which has been established principally by the works of Soviet scientists. In discussing the methods of complex climatology, we therefore refer mainly to the works of Soviet researchers.

We also point out that the appearance of many works on complex climatology is due to the painstaking work of Ye. Ye. Fedorov's closest assistants; namely, Ye. P. Gvozdeva and M. A. Sorokina.

One of the divisions of this work, i.e., "The Use of Principles of Complex Climatology in Medicine", was reviewed and supplemented by S. A. Sukharev.

The division stating the principles of complex-dynamic-climatological analysis was included in this book even though it was published in another work in order to maintain continuity.

THE BASIC METHOD OF COMPLEX CLIMATOLOGY

Section I - ~~The Basic Method of Complex Climatology~~

A. The Concept of Weather and Climate in Complex Climatology

Although a particular case of weather is practically non-repetitive, climatological studies require that some generalizations be made, and therefore the concept of types of weather is used. A weather type is understood to be the complex characteristics of weather described by certain definite properties, i.e., broad or narrow gradations of a large or small number of elements. It is apparent that one weather type, which includes a certain number of weather cases, may be repeated in the same locality and may be found in various locales.

Many causes influence the formation of weather, the most important of which are solar radiation, atmospheric circulation, and the underlying surface. The influence of the latter is felt particularly strongly in the lower atmospheric layers next to the earth within the limits of the roughness (friction) layer. (The roughness layer is understood to be the lowest atmospheric layers where the distorting influence of the underlying surface affects the dynamics of the air flow. The vertical extent of the roughness layer is naturally different under different conditions of relief and vegetation and also under different synoptic process.) Because of this, regions which undergo the same radiation and synoptic conditions but which differ in details of the type of underlying surface may have slightly different weather conditions. Therefore, the weathers which form in the lowest atmospheric layers and directly influence the ordinary practical activity of man and also the development of the vegetable and animal world, according to Ye. Ye. Fedorov's supposition, began to be called local weathers. Thus, local weathers began to be considered as different weathers emerging in the lower atmospheric layers under the influence of differences of the local landscape within the limits of one "synoptic" weather. We understand the latter as a weather which forms under the conditions of certain synoptic patterns, i.e., certain categories of air masses, types of frontal processes, etc., which to a considerable degree reflect only the influence of zonal characteristics of the underlying surface. This difference between "synoptic" and "local" weathers will be greater the more complex is the type of underlying surface at the point where the station is located, i.e., the less the given station will satisfy the requirement of synoptic representativeness. This difference will be manifested mainly in those components of the weather complex which are most subjugated to the distorting influences of position, such as temperature and humidity, wind conditions, colloidal state of the layer next to the earth, and also state of the earth's surface. Sometimes the type of geographical background (meaning the conditions of the vegetative cover and of topography) where the station is located will be so unique as to cause weakening of the connection between local and "synoptic" weathers. We must keep in mind, however, that weakening of the connection between local and "synoptic" weathers will also depend upon the type of general circulation processes over the given region.

Constant quantitative and qualitative changes in the state of ~~of~~ weather-forming factors determine a continuous change of local weathers in time. Moreover, aperiodic factors are often superimposed on those of a periodic nature, causing QUITE COMPLEX CHANGES ~~quite complex changes~~ of local weathers. These changes however are completely regular for definite conditions of the geographical medium and for ~~the~~ definite time. This regularity is first of all accounted for by the fact that the direction and limits of the quantitative and qualitative changes in the state of weather-forming factors ARE ~~are~~ to a considerable degree determined by the geographical conditions of the region, the time of day, and the season. This regularity MAKES IT IMPROBABLE ~~makes it improbable~~

~~[illegible] which are typical for [illegible]~~

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or impossible for local weathers which are typical in one season to appear in another season. It is also reflected in the frequency of various types of local weathers in one season and in the characteristics of their successive change from day to day. True, all these regularities undergo slight (or sometimes substantial) changes from year to year, but from the standpoint of a perennial period of many years, they create definite regime of local weather indigenous to the given region.

Thus, taking weather as the only real category of the physical state of the atmosphere, we have basis to assert that the climate of any region can be manifested only through local weathers. Starting from these assertions, we have recently in complex climatology started to understand climate as the whole set and regime of local weathers and the processes leading to a change in local weathers as these are revealed by the data of perennial meteorological observations in the region under study (Chubukov, 1946). This definition of climate is very close to that used in the work of B. P. Alisov and others ([illegible]),

This concept of climate naturally must lead to the development of new methods of climatological analysis which will first of all permit climate to be expressed through local weathers, i.e., through real meteorological sets. This particular direction of such climatological analysis has received the name "complex climatology".

The expression of climate through local weathers does not of course exclude the use of analysis of the perennial regime of the separate meteorological elements and phenomena, since the latter will permit classification of the climatic characteristics of the region under study but only in the part of the regime governed by these few individual elements and phenomena.

B. Classification of Weather Types

From what has been said above on the concept of weather and climate from the standpoint of ideas developed by the school of complex climatology, there follows the basic problem of a new approach in climatological analysis; i.e., to express weather with the help of a set of meteorological elements and phenomena.

This problem was solved by Ye. Ye. Fedorov ([illegible]) with respect to weather of entire days and by Nietela ([illegible]) with respect to the characteristics and expression of the weather of the moment by the method of translating the results of meteorological observations into letter formulas with the help of a special code. The substance of the method is as follows: By using the results of periodic meteorological observations (at 0700, 1300, and 2100 hours of former years and at 0100, 0700, 1300, and 1900 hours in recent years), a formula of the local weather of each day is drawn up by using (according to a special system) letters of the Latin alphabet.

This formula (Fedorov, 1925) always consists of four certain letters used in a definite plan according to the code system and a number for some of them (introduced after A. S. Uteshev's proposal in 1946).

For example, the formula for the weather observed in the Moscow region 20 July 1939 (the observatory imeni Mikhel'son) has the form

$$at^{27}_{16}U^{53}a.$$

(This formula is given in somewhat abridged form and contains only the so-called main letters. In some cases, when the values for the elements are close to adjacent gradations, additional letters are also used to clarify the weather type).

In this and similar formulas, each of the four letters express the following elements and phenomena:

The first letter of the formula (in this case the letter "a") characterizes the wind conditions of the region (speed and direction).

The second letter of the formula (the letter "t") characterizes the temperature conditions of the region. The letter takes into consideration the mean diurnal air temperature, the diurnal temperature amplitude, and the change of the mean diurnal temperature from the preceding day to the present day. The numbers with this letter give the minimum (below) and maximum (above) air temperature for the day.

The third letter of the formula (the letter U) designates the characteristics of the region with respect to cloudiness conditions, with respect to the average diurnal relative humidity, and with respect to precipitation conditions (or indicates the absence of the latter). The figure with this letter denotes the relative humidity at 1300 hours in percents and the amount of precipitation in the form of two specific indices placed beneath the letter (precipitation was not observed in the Moscow region on 20 July and therefore this formula does not contain these indices); the first index denotes the amount of predipitation through the night (1900 to 0700 hours) and the second in the daytime (0700 to 1900 hours).

The fourth letter of the formula (the letter "a" in the example) describes the state of hydrometeors on the earth's surface and takes into consideration a number of phenomena which are observed in the atmosphere on the given day.

The content of the formula given for the weather in the Moscow region on 20 July 1939 can naturally be revealed only with the help of code tables, which were first given in the work of Ye. Ye. Fedorov (1925). This code is given by us in tables. Some of them are given in the modernized (by T. I. Tsomaya) form (see the appendices at the end of the book).

By aiding the code tables, it is easy to draw up a picture of the weat weather which was observed in Moscow on 20 July 1939 as expressed by the formula: $at_{16}^{27}u^{53}a$.

This weather can be described in the following way. A moderate north wind with velocity varying from 3 to 6 m/sec was observed persistently in Moscow on 20 July 1939. The mean diurnal air temperature varies from 17.5 to 22.4° C with a maximum temperature of 27° and a minimum temperature of 16°. The amplitude of the diurnal temperature fluctuations ranged from 10 to 15° with a change of less than 5° in the mean diurnal temperature from the preceding day. Cloudiness both at night and in the day varied from 6 to 10; the mean diurnal relative humidity was 61-80%; the relative humidity at 1300 hours was 53%; no precipitation was observed; the earth's surface was dry.

We have introduced this example in order to show how quite detailed weather characteristics are given by a small letter weather formula. We have decoded one of these weather formulas. Ordinarily, the researcher is confronted with the reverse problem; i.e., to translate the results of meteorological observations into letter weather formulas with the help of code tables. This takk is not difficult and requires only technical skill. It is somewhat like the problem of translating the results of meteorological observations intt a system of synoptic telegrams, work that many meteorologists are very familiar with

In Table 1, we give an example of encoding meteorological observations into weather types.

Careful consideration of the structure of the code tables will convince the reader that the code proposed by Ye. Yei Fedorove not only retains the main weather features in the letter formulas but also characterises their most important details. This is attained by the fact that [redacted] several variations have been introduced in this system of symbols which is based on letters of the Latin alphabet, e.g., both small and capital letters are used, underlined and non-underlined letters, letters with a colon sign. Thus, there are a number of signs at the disposal of the investigator which can be used on any of the four places of the letter expression of weather. The number of all possible combinations of these signs is more than sufficient to express all the types of [illegible] weathers on the earth. The code is also [illegible], which facilitates its use. The [illegible] of the [redacted] code lies in that each place of the [illegible] letter weather expression is given to a definite group of meteorological elements and phenomena and the letter symobols are used in a definite system (for example, for weathers without precipitation only vowels are used in the third letter of the formula, and for weathers with precipitation, only consonants).

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The separation of [redacted] wind of constant direction and a wind of [illegible] changing direction by a clock-wise and counter-clockwise [illegible] problem of wind characteristics [redacted] for relatively stable and moving pressure fields of various types and for intra-mass and frontal processes. By introducing a small supplement to this part of the code, we can also describe [redacted] wind conditions for breeze circulations and also the diurnal behavior of wind velocity.

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The characteristics of the temperature regime of the region, as we have seen above, includes not only the mean diurnal air temperature, but also the amplitude of diurnal fluctuation and in addition the change of air temperature in comparison with the preceding day. The mean diurnal air temperature by itself does not give a sufficiently accurate picture of the temperature regime. But the indication of the diurnal temperature amplitude together with the diurnal temperature maximum and minimum gives quite complete characteristics of the temperature background not only for the day as a whole, but also in periods of radiation peculiarities of day and night. All these characteristics are useful because they are extremely different under different conditions of the relationship of advective and radiation processes. In addition, the sign and magnitude of the change of mean diurnal air temperature in comparison with the preceding day clearly indicates the direction and intensity of the temperature change, which is especially useful for two reasons; namely: 1) for establishing the time when the temperature approaches thermal equilibrium, a very important characteristic of the transformation process and 2) for the characteristics of the jump-like (discontinuous) temperature change when frontal divisions are traversed. Both, of course, are extremely important for the analysis of the consecutive change of weather for any given period.

In the part of the formula describing cloudiness, humidity, and precipitation conditions, we find the very important subdivision of all weather's into weathers with and without precipitation. In the general group of weathers without precipitation, cloudless weathers and weathers with clouds of various forms and amounts are distinguished. The first characterize the atmospheric state when processes developing in the atmosphere clearly prevent the emergence of clouds. This can be observed when there is a sharply-defined subsidence of a large tropospheric strata, leading to the formation of powerful inversions in those cases where they form beneath the condensation level, which obstructs the transfer of water vapor from the lower into the higher layers of the troposphere. Weathers with low cloudiness, or cloudy at various times of the day, or very cloudy but without precipitation represent a group of different conditions of the physical state of the atmosphere. In all the preceding cases, apparently, we have the development of ascending currents of various types and various intensities. These reach the condensation level, causing cloud formation. Since these clouds do not produce precipitation, we may assert that the cloud layers are in a state of stable colloidal equilibrium. On the other hand, weathers with precipitation first of all indicate that the physical state of the atmosphere is not only favorable for the formation of a cloud mass, but also provides for the transition of its structure into a state of unstable colloidal equilibrium. True, the factors and processes which promote this conditon may be quite numerous and quite different. Nonetheless, we can obtained some idea of their nature from the code system. For example, the development of powerful anabats as a result of the resolution of the energy of moisture instability in INTRA-mass processes often leads to the formation of [illegible] which MAY be regenerated into cumulus rain clouds which produce showers. AND SINCE this process in continental regions most often occurs in the daytime of the warm half-year and does not produce a solid cloud cover [illegible] ly will lead to the formation of a definite weather type [illegible] day, which finds expression in the fourth well as in the third symbol of the letter formula. The other process, the formation of clouds and fall of precipiation in fronts, is often characterized by the development of a solid cloud cover, which may be maintained for the major part of the day and give prolonged precipitation. These characteristics in cloudiness and precipitation conditions again find expression by the various letter symbols entering the table as the third letter of the code.

The make up of the table for the fourth letter of the formula in the code, i.e., the characteristics of various phenomena in the atmosphere and the state of the earth's surface, is supposed to cover almost all the more important meteorological phenomena on which observations are conducted at meteorological stations of the second rank. This table gives not only the phenomena itself, but also clarifies the picture of the times when it was observed. To a certain degree, this table permits one to judge the duration of the phenomena, particularly in those cases when the phenomena is observed continuously through the intervals between the four hourly observations. Along with the practical value which these characteristics have in themselves, another should be mentioned. The introduction into the weather code of such phenomena as thunderstorms, dews, hour-frosts, fogs, and others, makes the picture of the meteorological complex of a weather type more thorough. It permits one to gain some idea of the characteristics of the physical state of the lower tropospheric layers at the time when the above-mentioned phenomena develop.

The structure of the weather code tables discussed gives a picture of the completeness of the weather characteristics for a day used in Ye. Ye. Fedorov's method. Naturally, we should not take a dogmatic approach to the methods for complex expression of the weather which have been described, since these methods were proposed only for purposes of general climatological descriptions. We may consider it desirable, however, to expand the characteristics of a weather type even for this use of complex climatology. Such expansion is possible and in principle is limited only by the completenes of the meteorological observations, the program for which varies in stations of different types. The composition of Ye. Ye. Fedorov's code tables is basically designed for the program of meteorological stations of the 2nd rank, the observations of which are most frequently used for climatological descriptions of various types.

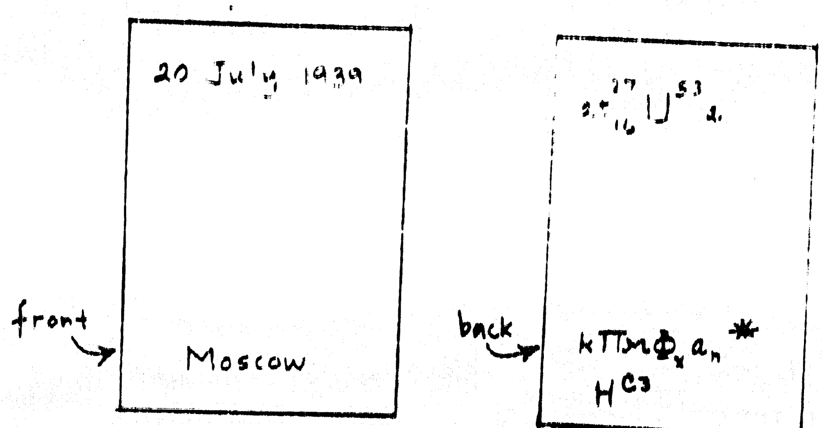
Here we turn the attention of the reader */ to another principle of the code, namely to the gradations selected for various elements. They are naturally conditional to a considerable degree, but for purposes of general climatological descriptions, those limits at which the characteristics of wind velocity, temperature, humidity, etc. are selected are selected successfully. These gradations [illegible] [illegible] in calculating the frequency of a value for an individual element within the selected limits. [illegible] breakdown would be inefficient, however, since it would considerably complicate processing. We should remember in regard to this that, having taken weather types as a basis for analysis, we should not strive toward excessive breakdown of the regime of a given element, since each such element is clarified (broken down) by the set of other components of the complex.

In the future, when the processing of the results of meteorological observations will be mechanized, we can expect a transition to the use of punch card archives for classification of various weather types. In mechanized processing, various complexes can be classified which are in no way limited by the conditional designations of the [illegible] work "Samples of Meteorological References according to a Mechanized Card Catalog", Gidrometizdat, 1946, for the potentialities and engineering of mechanized processing of the results of meteorological observations. */

C. A Catalog of Weathers

After the results of daily meteorological observations are translated into letter expressions, i.e., detailed weather types, the latter are copied down on special cards (a separate card for each day). A set of these cards makes up a catalog of the weathers of the given stations

The date of observation and the name of the station is shown on the face of each card. In the upper part of the reverse side, the formula of the weather type is given, and in the lower part (at L. A. Chubukov's suggestion) certain data is given from the calendar of air masses and fronts.



*Note: The middle three letters are Russian; in Latin $kPmF_x a_n$.

Fig. 1. Sample of a Card of the Catalog of Weathers

This data is ordinarily limited to the name of the air mass and front (if the passage of a front was observed on the given day) and an indication of the circulation type (form of the pressure level). A sample of such a card is shown full-size in Fig. 1. There is ample space on the card for writing in any numerical characteristics which were not included in the code.

The use of dynamic climatological information in the weather catalog permits one to establish many of the elements in the genetic basis for the formation of local weather. For example, in our particular example, the information taken from the calendar of air masses and fronts indicated that the given weather type emerged under the influence of continental polar air of maritime origin (kPm) and the following passage of a cold front (F_x), after which advection of previously Arctic air (a_n) took place. This process was developed in the northwest sector of a cyclone (H^{C3}).

In principle, the way in which the catalog of weathers is drawn up is the same for the different methods of complex climatology; however, it should be pointed out that the method of card catalogs of weathers was first devised and used by Ye. Ye. Fedorov (1925). The method which he devised obtained wide usage not only in works on complex climatology, but was also borrowed by [redacted] researchers for works on dynamic climatology.

The part of the weather catalog containing the weather formulas [illegible] present basic data for [illegible] climatological analysis, but these catalogs are drawn up for a number of [illegible] stations of the region under study for a [illegible] period (usually for [illegible] years). It is still difficult to [illegible] more than 20 years for the entire network of stations because the observations on the entire complex of elements used or their separate components were [redacted] not [redacted] of sufficiently high
[redacted] quality and also because of the laborious nature of the work.

The investigator having a catalog of weathers of a certain station at his disposal can express the climatic characteristics of the region where the station is located through the frequency of weather of various types by simply counting up the cards. This weather catalog also makes it possible to trace the type of change of weather from day to day in the analysis of any synoptic process, which is extremely important in works on dynamic climatology. Finally, the catalog of weathers is a very convenient form for works in the field of applied climatology, of which we shall speak in detail later.

Section II - APPLICATION OF THE BASIC METHOD OF COMPLEX CLIMATOLOGY TO GENERAL PROBLEMS IN THE STUDY OF CLIMATE

A. Expression of Climate in Weathers

We first consider only the use of the weather catalogue to establish the frequency of weather types, which is accomplished by counting the number of cards with a certain weather type.

The results of such a count are ordinarily ~~are~~ copied down in tables of special form. We will not describe the composition of the tables in detail, but merely give the principles of their construction. Two completely different weather groups, i.e., weather without precipitation and weather with precipitation, are subdivided. Within these groups, the weather types are characterized by conditions of wind velocity, mean diurnal air temperature, cloudiness conditions, and mean diurnal relative humidity. The other elements which are included in a weather type are usually disregarded here.

In these and similar tables, the weather type is determined by the intersection of the corresponding horizontal bands and vertical columns. Within the square obtained in this way we find the number expressing the frequency of the given weather type. The tables therefore permit one to obtain a clear picture of the types of weather which predominate in the region under study.

As an example of such a table, we introduce Table 2,* which was borrowed from the work of Ye. Ye. Fedorov (1934). Data on the frequency of weathers obtained by counting the number of cases observed in the Moscow region in the month of May is given in this table, which we show in somewhat simplified form.* [Note: for Table 2, see original document.]

From the table, we conclude that certain weather types had comparatively high frequency in May in Moscow. These are weather with little cloudiness, no precipitation, a moderate wind or a wind only in the daytime, with mean diurnal air temperature from 12.5° to 17.5°, and with mean relative [illegible] tive humidity from 41% to 60%. Among such weathers, we note those having frequency of 13 or even of 17. On the other hand, we see in the table a large variety of weathers with comparatively low frequency. We find weather types with frequencies of 1, 2, and 3 in large numbers. The large variety of weathers is a typical feature of the climate of moderate latitudes and the data for Moscow illustrates this convincingly. Naturally, there will be considerably less variety of weather types under conditions of other climatic zones with [illegible] stability of [illegible] processes. As a consequence, the frequency of each weather type separately will be considerably higher and the general form of the structure of the climate in weathers considerably simpler.

B. Classes of Weathers

Researchers in the field of complex climatology consider it possible to progress towards further simplification of the expression of the end results of statistical computations; i.e., to further simplification of climatological tables. For this purpose, Ye. Ye. Fedorov subdivided the whole variety of weathers into classes, ~~from the~~ mainly from the standpoint of the characteristics which are of practical important for agriculture and for the life of man. This can be done only by efficient unification of weather types in broader groups.

The following classes of weathers were set up (see Table 3). [Note: See Table [illegible] for [illegible]]

Among these weather classes, the first eight (I-VII, XVI) are characteristic for the warm season of the year; weather classes VIII and IX are most frequently weather of the transitional seasons (when dealing with the climate of moderate latitudes); the last 6 weather classes (X-XV) can be called winter weathers.

The make-up of the weather classes which are differentiated in complex climatology is accurately defined and is shown by used in two figures. Weathers of the warm half-year are shown in Fig. 2 and of the cold half-year in Fig. 3. The make-up of weather classes shown here is changed slightly from the form published previously (Chubukov, 1947[illegible]). For the reader's convenience, the make-up of weather classes (with respect to the more important meteorological characteristics) in these tables is shown by conventional designations. The conventional designations are given separately in Fig. 4.

As seen from these tables, the weather classes of the warm season are differentiated by the conditions of mean diurnal temperature, mean diurnal relative humidity, cloudiness, precipitation, and also sometimes by wind conditions. The weather classes of the cold season are classified merely by the mean diurnal air temperature conditions and all (with the exception of one, namely, "slightly frosty) are subdivided into weathers with wind and without wind.

Some of the most dangerous weather classes for agriculture, such as [illegible]-dry and moderately dry weathers were established by Ye. Ye. Fedorov in a completely objective way. This class included weathers observed in periods preceding [illegible] loss or a poor state of grain crops caused by a drought or a dry period. The principle used for classification of the other weather classes suffered from a greater or lesser degree of arbitrariness, but these weather classes could be adjudged completely satisfactory from the standpoint [illegible] practical problems.

As we have previously stated, the weather classes enumerated above do not have genetic basis. But each case of a certain weather class can be analyzed supplementarily in order to clarify its genetic characteristics on the basis of the [illegible] of dynamic climatological reports which we find in the [illegible] catalog of weathers. However, it should be noted that some of the weather classes used in complex climatology imply such genetic basis for the predominant number of cases of weathers within the limits of one class.

We pointed [redacted] this out eablier when we discussed the structure of the code, by considering, for example, the differences of cloudy weathers in the daytime, with precipitation and without precipitation, or theses reasons for the formation of rainy weathers. We might also point out that moderately dry and drought-dry weathers in the[redacted] middle of summer on the Russian plain always arise in periods of [redacted] well defined radiation transformation when continental-polar (first) air masses are heated or in advection of continental-tropica (second) air (Chubukov, 1940).

Having noted the absence of a clearly uphold genetic foundation in the classification of local weathers used, we again turn our attention to its strong side; namely, each weather class is strictly defined in its numerical characteristics of the complex formed. [redacted] Thus, this classification can be used for objective work in analyzing [redacted] meteorological observations, which cannot for the meantime be said for purely dynamical climatological investigations.

C. Expressing the Structure of Climate in Weather Classes

If the climatic characteristics of the region where a station is located are expressed through the fre uency of weathers of various classes, the general form and composition of the climatological tables will be very simple and easy to handle. We illustrate this by the example of Moscow [redacted] for the region where the observatory connected with the Timiryazev Agricultural Academy is located

[redacted]Table 4, which we borrowed from Ye. Ye. Fedorov, [redacted] gives the frequency of weather classes in Moscow for all months of the year, expressed in the number of days with weather of a certain class (in this table, some freezing weathers in individual months are not subdivided into weathers with and without wind).

The data of similar tables, compiled for any station for all months of the year, can be used to express the climatic characteristics of the region where the station is located in even more convenient graphic form, as was proposed by A. I. Baranov. As an example of this possible representation of climate in weathers, we give Figs 5, 6, and 7,* made for several [illegible] different climatic region. Moscow is shown as [illegible] of the western regions of the USSR, which lie [illegible] the southern taiga and composite forests with the [illegible] steppe and bear clear marks of a boreal climate with [illegible] distribution of precipitation throughout the year (Koppen's climatic formula DL). [illegible] illustrates the charac[illegible] steppe [illegible] found in the southeast [illegible] (Koppen's climatic formula [illegible]). [illegible] characterizes the climatic conditions of the deserts in the Aralo-Caspian lowland with clear cold winter (Koppen's climatic formula DBWa). *(Note: See the appendix)

In the upper part of these figures, the structure of the climate is expressed in weather classes, depicted in designations which we have already described. The months of the year from January through December run from left to right at the top of the figures; along the verticals are given the frequencies of the weather classes, shown by the width of the band (considering that the total width of the upper part of the figure corresponds to 100% frequency; i.e., to all observed cases of all weather classes) in the proper cross-hatching, according to the designations adopted in Fig. 4. This method enables one to easily establish not only the period of the year when a certain weather class will be found in the region, but also to find its frequency even in the separate ten-day intervals of this period.

The graph of the structure of the climate in weathers is supplemented by a diagram of the yearly behavior of air temperature (curves of the yearly behavior of mean monthly temperatures and broken lines for the extremal temperatures) and the yearly behavior of precipitation (monthly precipitation totals) at the station investigated (lower parts of the figures). The latter data is naturally calculated by the usual method used in the climatology of the separate elements or more often is simply selected from climatic handbooks. When necessary, other information of this type may be used. The lower parts of the figures, therefore, depict the perennial regime of the separate elements as a result of the influence of the entire set of weathers upon the regime of the given element. Strictly speaking, the observation periods used for construction of the upper and lower parts of each figure should be homogeneous, but this is still difficult to attain.

It should be pointed out here that the figure depicting the structure of the climate in weathers (the upper part of our figures) may if the researcher desires be made more detailed with respect to other components of the weather complex. For example, cloudiness conditions and cases of weathers with fogs, snowstorms, etc. might be introduced into the weather classes of the cold season. Similarly, it might be useful sometimes to introduce wind conditions and note the frequency of such phenomena as thunderstorms, dust storms, etc. in the weather classes of the warm season. Even in the form shown in the figures, however, the structure of the climate in weathers reveals the main features of the climate of the region where the station is located.

All specific characteristics of the climates of the corresponding regions can be established from the figures shown of the structure of the climate in weathers. Since we do not care to discuss the climate of these regions in detail, we note only their main features.

In the central regions of the Russian plain (Moscow), extensive development of cloudy, overcast, and rainy weathers is observed at night in the warm seasons, arising most probably either as a result of frontal processes or under conditions of cold advection. Another clear characteristic of the climate of this region is the sharp increase in May of warm weathers with diurnal cloudiness which remains almost unchanged in its frequency for the remainder of the summer. Weathers of this type result from the radiation transformation of the heating through of air masses, but only when the thermal convection currents reach the condensation level, which is not apparently observed so frequently in this region.

As a result of the set of rainy, cloudy weather with precipitation, a summer precipitation maximum is obtained, which is typical for this region. Other types of weathers, such as low-cloudy, non-arid, whose frequency is especially high in May (about 30%) and September (about 25%) are of great importance in forming the weather. Although the frequencies of these weathers are not high, very high temperatures are observed in the short periods when they form. In winter, moderately freezing weather with wind is most frequent, but there are also cases of severe freezing weather; the latter are not shown on the figure because of their low frequency (Chubukov, 1947). There may also be separate cases of drought-dry weather which are not shown on the figure. In the middle of summer, moderately dry weathers are frequent.

Under the conditions of steppe (Fig. 6) and particularly desert (Fig. 7) regions, the frequency of local weathers in the warm half-year merits special attention. For example, in the middle of summer, the total frequency of moderately dry and drought-dry weathers reaches 60 (Ural'sk) and even 80% (Kzyl-Orda). Incidentally, the structure of the climate in weathers of Kzyl-Orda is shown in simplified form; freezing weathers are not subdivided into weather with wind and without wind, and the classes of the warm season are not clarified with respect to temperature gradations. This high frequency of moderately dry and drought-dry weathers in steppe and desert regions is the clearest feature of their climates.

This type of figure, showing the structure of the climate in weathers of a certain point, may also be useful as representative diagrams for various climatic zones.

D. Investigation of Vertical Climatic Zonality

The data of meteorological stations situated at different heights but close to each others in regions with shapply broken terrain on the frequency of weather classes can be used to construct a picture on vertical climatic zonality in such regions. Even in this case, it is useful to use graphic methods of representing the vertical [illegible] of frequency as well as [illegible] frequency [illegible] weather classes.

As an example, we [illegible] represent [illegible] frequency of local weathers in one of the southern mountainous region for July (Fig. 8). At the lower levels, we note the very high frequency of drought dry weathers, showing the influence of the desert adjoining the mountains. The frequency of this type of weather remains practically unchanged (about 50%) at the lower boundary of the steppe belt. Within the steppe belt, the frequency of drought-dry meteorological complexes decreases noticeably with height and becomes comparatively low close to the lower boundary of the forest-meadow belt (about 20%). At the upper levels of the forest meadow belt, drought dry weathers are [illegible] observed. The frequency of moderately dry weathers has [illegible] vertical distribution. Moderately dry weathers are [illegible] frequent in the zone of desert influence, but the decrease of their frequency with height cannot be compared with that for drought dry weathers. [illegible] approximately 2,000 meters, the frequency of moderately dry weathers has decreased by only 15% in comparison with the frequency at the very lowest levels. In the middle and upper parts of the forest-meadow belt, the frequency of moderately dry weathers remains practically unchanged. Again, the appearance of moderately-dry weathers even in the lower zone of the belt of Alpian meadows is not rare. Higher, however, in the upper parts of the Alpian meadows belt, formation of moderately-dry weather is not so probable, and in the belt of permanent snow and glaciers, this weather is not in general observed.

Because of the decrease of frequency of drought-dry and moderately-dry weathers at the heights of the forest-meadow belt and the alpian meadows best, low-cloudy, non-dry weather is quite frequent.

Another important characteristic of the vertical zonality of weathers in this region at this time of year is the increase in the frequency of weathers with cloudiness in the daytime and rainy weathers with height.

The vertical zonality of local weathers will naturally differ greatly from that described in regions with other geographical conditions. For illustration, we introduce Fig 9, which shows (according to A. I. Baranov) the vertical distribution of the frequency of various weather classes in July for the southern slope of the Crimean mountains, along the line Yalta-Ay-Todor-Eriklik-Tyusler-Ay-Petri. The influence of the sea here in summer is shown in the low frequency of drought-dry weathers at the very lowest levels and in their almost complete absence at heights above 500 meters, even though the frequency of moderately-dry weather is quite high and almost unchanged up to heights of 700 meters (we note that warm, cloudy in the daytime and cloudy, night weathers are not subdivided into weathers with and without precipitation on the figures showing vertical zonality of local weathers).

E. Investigation of the Climatic Characteristics of Large Areas

The well known approach of isoline construction can be usefully applied in the climatic analysis of a large area where the problem of the geographical distribution of weather classes plays a leading role. This method was first used in complex climatology by Ye. Ye. Fedorov (1934b, 1938). This methode consists of the following: The frequency (in percents or in the number of cases) of days of a certain weather class in the given month is set down on a geographic map for the location of each point (station). Then, curves, frequency isolines, are drawn through points with equal probability of a weather class. The system of isolines constructed in this way

We have shown only maps of the frequency of drought-dry weathers as an example of the ~~type~~ nature of the geographical distribution of one of the weather classes under conditions of the Russian plain and east Kazakhstan. If we were to analyze the climatic characteristics of the summer seasons, we would naturally have to draw up and analyze maps of the distribution of frequency for each weather class observed in this period. Thus, the researcher must analyze the series of maps for the distribution of frequency of various weather classes in order to describe the climatic characteristics of the given region in detail. But each such map illustrates only the regularities in the frequency distribution of the individual weather class. Analysis of a series of such maps would still not permit the investigator to draw up a clear picture of the regularities of the spatial change of the entire structure of climate in weathers for the area studied in the given month.

To supplement such maps, therefore, we have used since 1947 special graphs, suggested by Ye. M. Baybakova, of the climatic characteristics, showing the change of the structure of climate in weather along judiciously selected lines which cross the the area under study in different directions.

To illustrate, we show Figs. 12, 13, and 14 [illegible] by Ye. M. Baybakova, which show the [illegible] of [illegible] weathers in the south Russian plain [illegible] along [illegible] N. L. These three figures give a clear picture of the change of the structure of climate in weathers in July in the Russian plain along the lines selected.

Graphic analysis of this type is also very useful in our opinion for the study of the change of the structure of climate along narrow river valleys.

clearly reveals the regularities of the geographical distribution of the given weather class, and the climatic characteristics of the separate areas of the region investigated stand out sharply. Obviously, for similar thickness of thenetwork of meteorological stations, the method of construc-ting isolines of equal frequency for a certain weather class would be of great use for a flatland country. It is [illegible] to con-struct a system of isolines which best represents the actual distribution of frequency for a given weather class [illegible] areas. Nonetheless, the method is still quite feasible even for these regions, especially in a zone where flatland regions join with mountainous areas.

To illustrate, we introduce two maps of the distribution of days with drought-dry weather: one for the European USSR (Fig. 10) and the other for the region of east Kazakhstan (Fig. 11).

The map of the distribution of drought-dry weather on the Russian plain shows the high frequency of this weather in the month of July on the southeast part of the plain and the decrease of frequency in the northwest direction. Isolines of zero frequency of drought-dry weathers separates the regions (north of the line of zero frequency) where the in-fluence of these complexes is practically excluded.

In east Kazakhstan, the distribution of frequency of drought-dry weathers is considerably more complex because of the more complex struc-ture of the surface. The frequency of drought-dry weathers is very high in the regions of the deserts bordering Lake Balkhash, in the Ili River valley, and in the Ala-Kul' and Zaysan basins. In the mountainous regions of Altay, Tarbagataya, Dzhungar Ala-Tag, and the Trans-Ili Ala-Tau, how-ever, the frequency of drought-dry weathers decreases sharply to zero with height. It is also low in the northern part of east Kazakhstan; i.e., in the region where the Irtysh River flows out on the West Siberian lowland.

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To illustrate, we show Figs. 12, 13, and 14 [illegible] by Ye. M. Baybakova, which show the structure of [illegible] in weathers in the south Russian plain [illegible] along 50° N. L. These three figures give a clear picture of the change of the structure of climate in weathers in July in the Russian plain along the lines selected.

Graphic analysis of this type is also very useful in our opinion for the study of the change of the structure of climate along narrow river valleys.

F. Principles of Regional Division by Climates in Complex Climatology

The method of climatic regional division devised by Ye. Ye. Fedorov is based upon the maps of the distribution of frequencies of various weather classes. The principal distinction of this method is that places of thickening of isolines on the maps are used to find the boundaries between regions.

It is quite obvious that a more or less sharp change of climatic conditions occurs in these places. The greater the number of weather classes that participate in this thickening and the more intense the thickening, the more definite are the boundaries. We see that Ye. Ye. Fedorov's criterion is completely objective and even, one might say, natural. It does not suffer from arbitrariness, which distinguishes it favorably from the methods of regional climatic division in which the authors adopt a certain isothermal, isohyet, etc. for climatic boundaries, which practice cannot be said to be have firm scientific basis.

These principles devised by Ye. Ye. Fedorov were first used for climatic regional division of the Russian plain, for which ~~it was possible~~ quite detailed regions were isolated. The climate of each of these regions could be characterised by their peculiarities, which stood out quite clearly both in the tables of frequencies of various weather classes and also in the climatic graph of the representative station for the regions.

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III. INVESTIGATION OF THE ORIGIN OF LOCAL WEATHER

A. Complex-Dynamic-Climatological Analysis

The methods of complex climatology thus far described permit us to establish the structure of climate in weathers, to clarify the general picture of the vertical zonality of weathers in mountains, to gain some idea of the nature of the geographical distribution of a certain weather class within an area, and finally, to make a climatic regional division of large areas. The solution of these problems in itself is of great importance in contemporary climatology and should not be underestimated. But in theoretical climatolggical studies of local weathers, we must also reveal the laws of their formation and changes in time and space under the influence of the most important factors. We consider the most important factors to be conditions of the radiation balance, the characteristics of atmospheric circulation, and the type of underlying surface at the point or region of investigation. This trend alone in climatological investigations will produce in the future a scientifically-based interpretation of local climatic characteristics.

Up until recently, the problem of the formation of local weathers could not be solved satisfactorily because the methods of climatological analysis used could not clearly isolate the influence of some weather-forming factors from others. The attempts made in the analysis of the relationship of local weathers with synoptic patterns, namely with different classes of air masses and fronts and different circulation types (Fedorov, 1935; Maksimov, 1938, Chubukov, 1939) did not produce important results. At that time, (1) the investigators could not isolate or separate the more or less homogeneous cirmulation conditions and (2) they used formal statistical methods which did not permit them to analyze the emergence and subsequent change of local weathers.

Although the first results of the analysis of the frequency of emergense of a certain weather type under conditions of definite air masses and circulation patterns were obtained in these works, these results often [illegible] [illegible] disappointment. It was established that under conditions of one and [illegible] the air mass and of one regicon and approximately of the same period (for example, a certain month) a great many different weather types could be observed. It was found, on the other hand, that one and the same weath - er type could emerge in different air masses. Such diversity in the relationship between weather types and synoptic patterns gave some authors [illegible] reason to state that the indefiniteness disvovered eliminated [illegible] possibility of finding this type of characteristics by the for- [illegible] impossible. Thus, it was necessary to find new methods of solving the problem of the formation of local wather.

Experience in solving this problem has recently been obtained by synthesizing the methods of dynamic and complex climatology. This method of analysis, devised by the author, was called complex-dynamic-climatological analysis.

In complex-dynamic-climatological analysis, local weathers are expressed as they were adepted in complex climatology, while the formation of local weathers is traced within a definite interval of homogeneous synoptic processes. The laws of formation of local weathers are revealed by investigating the dynamics of local weathers simultaneously throughout the territory of the region under study on consecutive days of the synoptic periods selected.

The basic materials for such investigations are: 1) a catalog of weathers, supplemented by reports from a calendar of air masses and fronts, and 2) operational synoptic maps with all the data of contemporary aero-synoptic analysis.

The structure of the synoptic periods within which the dynamics of local weathers are studied is of the following form: preceding position-intrusion-transformation process.

The preceding position is characterised by ~~the~~ air mass occupying the region before the beginning of a new intrusion and by the type of local weather.

The time of intrusion for non-stationary fronts is identified (conditionally, to a certain degree) with the time when the front passes through. Intrusions of different air masses are naturally analysed separate. In addition, it has been found useful for the summer to subdivide frontal processes into two groups; namely, a) fronts expressed in cloudiness and precipitation, and b) fronts without cloudiness (or with low cloudiness) and without precipitation.

It is important to distinguish three types of air mass transformations:

1) Radiation transformation of heating (RT_+), which occurs when the radiation balance is positive, or radiation transformation cooling (RT_-), when the balance of radiant energy is negative.

2) Dynamic transformation of anticyclone settling (DT), in which some of the conservative properties of the air mass remain almost unchanged, but the hygrothermal characteristics of the local weather type undergo marked changes.

3) Orographic transformation (OT) observed only in mountain regions when an air mass passes through a mountain range and then only when the condensation level over the windward slope lies below the height of the range.

With this system of investigation, it is possible to isolate quite clearly the influence of the more important factors upon the formation of local weathers. Actually, if we speak of analysing the emergence and subsequent change of local weathers within a restricted region and in periods of homogeneous synoptic situations, then any difference in local weathers emerging at various points of the region under study, must be caused by purely local conditions. Among the latter, the more important are: differpeculiar

ences in the type of underlying surface exposition, conditions and [illegible]ities in the orographic background. These taken together could somewhat change the radiation balance and even cause the development of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the development of local weathers and their subsequent change is studied with respect to the system of the natural atmospheric process (intrusion and then transformation of the air mass), the entire manifold of these influences can be taken into consideration in the study of the corresponding periods of the isolated processes.

We consider it necessary to illustrate use of the method in some detail. As a partial example of the system described for analyzing the formation and dynamics of local weathers, we give an example for the territory of east Kazakhstan. In Fig. 15, we give the distribution of local weathers and their subsequent change for various regions of east Kazakhstan during a period of one of the intrusions of Arctic air (A) and its subsequent transformation into continental polar Siberian air (P_c). Processes of this type are quite frequent here in winter and are therefore of great practical and theoretical interest.

The figure was constructed in the following way: The stations of east Kazakhstan which were used are located in a rough north to south line from Semipalatinsk to Podgornyy. Stations of the height profile on the northern slope of the Trans-Ila Ala-Tau are given separately in Fig. 15. Each day of the period is represented by a rectangle with a small circle in its center. The weather class is indicated in the left side of the rectangle by a Roman numeral; the Roman numeral superscript "I" denotes the second low temperature gradation of the local weather class. Thus, the temperature characteristics of the weather class in this figure are given with an [illegible] error of no more than 5° of the mean diurnal temperature (we remind the reader that the weather classes of the winter period (with the exception of X) were distinguished in 10° intervals). The comparatively rare cases of warm weathers with mean diurnal temperature slightly higher than 0° are shown by the numeral III. The circle in the center of the rectangle corresponds (by the type and degree of its shading) to a definite state of the cloud cover. To the right, below this circle, the precipitation is given in the accepted symbols and fog phenomena are noted. The wind force according to an arbitrary scale is noted by the arrow above the rectangle; an arrow without feathering denotes a gentle breeze (wind of Beaufort force 3) and the absence of an arrow indicates a calm (the wind was not given for the Zyryanovsk and Myn-Dzhilki stations). The relative humidity is indicated in the right column of the rectangle by the code letters 1, 2, 3, 4 and the lambda symbol "Λ" with the following correspondence: Λ: 91-100%; 1: 61-80%; 2: 47-60%; 3: 21-40%; and 4: 0-20%. Relative humidity from 81 to 90% is indicated then by the absence of a number of symbol.

The first day of the period is always represented by the first vertical column from the left. The rectangle corresponding to a certain station gives in the first column an idea of the type of local weather for the day preceding the intrusion of the cold front. This day has to be included in the analysis of the period under consideration, since comparison of the type of local weather for the day up to the time of the cold intrusion with the type of local weather of the day of intrusion gives an idea of the rapidness of the weather change. This is very desirable since the direction and magnitude of the rapid change in the type of local weather depends not only upon the meteorological characteristics of the cold intrusion, but also upon the type of local weather of the day before the intrusion.

The second vertical column from the left characterizes the local weather on the very day of the cold intrusion (Φ_x); i.e., weather formed under the influence of a clearly expressed frontal process.

The third and last vertical column from the left details the types of local weather formed under anticyclogenesis conditions. The position of the anticyclone center, however, does not remain unchanged during the entire period. Winter processes of this type over Kazakhstan are frequently such that the anticyclone field forms with a center over the central regions of Kazakhstan in the first days following the cold intrusion. In the following days, the anticyclone center usually shifts to Altay (D$_2$). Thus, in the first days of anticyclogenesis, the territory of east Kazakhstan is on the eastern periphery of the anticyclone, then shifts into its central region, and finally lies on the western periphery of the anticyclone in the last days of the period. In conformance with this, local weathers in east Kazakhstan in the first days of anticyclogenesis form under the influence of radiation transformation of cooling (RT-)* and possibly continuing slight advection. In the following days, the influence of radiation transformation is intensified almost up to complete domination. During this entire transformation period, there is reason to expect continuous intensification of the cooling process and a changeover of the local weather type into a class of weathers with lower temperatures. But with a transfer of the anticyclone center to Altay, the influence of anticyclone settling, accompanied by a gentle breeze from the southern half of the horizon; i.e., the influence of dynamic transformation (DT) is superimposed upon the process of radiation transformation of cooling. The influence of the latter is displayed mainly in the higher levels, but often encompasses regions of low-altitude stations as well. Consequently, in these days the influence of radiation transformation of cooling is either weakened or completely suppressed. If the latter is true,

*Note: In the original document, this was written exactly thus : PT. Unfortunately these may be Russian letters "P" (corresponding to Latin letter "R") and "T" (same as Latin "T").

we observed another change of local weathers, namely a changeover from colder to warmer local weather classes. Naturally, everything stated above on the transformation period applies to the transformation process which act upon an air mass only from the time that they enter the tarritory of east Kazakhstan. Then we must also remember that variations of the subsequent intercombination of transformation processes may be quite different even through they do not violate the system described. In addition, some intramass processes may develope which will violate these laws; e.g., the emergence of strong local breezes. The latter, by causing intensified dynamic mixing of the lower and higher layers, can weaken the cooling process.

Fig. 16, showing vertical zonality of local weathers on the northern slope of the Trans-Ila Ala-Tau in the period investigated, has the same structural scheme. The relative position on the figure of the meteorological stations used, in slightly distorted and nonuniform scale, gives some idea of the height of one station above another.

We can descibe the content of the figure after noting one more important fact relating to the character of the underlying surface in periods of Arctic intrusions. Arctic intrusions into east Kazakhstan in the winter often either spread a fresh snow cover before them as a result of condensation processes in the front or take place over a previously established snow cover. Thus, in such periods, the entire territory of east Kazakhstan is represented by a homogeneous underlying surface, namely a snow cover. We now turn to the data of our figure.

Before the intrusion of Arctic air, the region of east Kazakhstan was occupied by a short-period domination of polar Turan air (P_T). Cloudy moderately cold weather with precipitation (XI class) was established on almost the entire territory occupied by P_T air. The moderately cold weather was accompanied by a clear sky only in the extreme south. The absence of a cloud cover in the P_T air mass in the extreme south was due to the influence of mountain ranges upon the dynamics of the air flow which influence caused a transverse divergence of [redacted] flow lines [redacted] on the leeward slopes of mountain ranges (the foehn effect).

The cloudless weather in the south, together with the foehn effect, determines the inversion nature of vertical zonality of local weathers in the mountain regions of the Trans-Ila and Dzhungar Ala-Tau. Thus, at a height of about 1 kilometer on the northern slope of the Trans-Ila Ala-Tau, the formation of slightly cold weathers (X weather class in the region of the Alma-Ata Geophysical Observatory) is observed, while warm weather is noted in the Medeo region ([redacted] designated by the numeral ...). We also have a similar type of vertical zonality of local weathers in the north (Sarkand) and south (Kos-Agach) slopes of the Dzhungar Ala-Tau.

On the second day of the period, a fairly low northwest intrusion of arctic air, which had been brought about in the tail of a cyclone, encompassed ~~almost~~ the entire territory of east Kazakhstan. It spread in the south ~~slightly below~~ almost up to 3 kilometers into the lower layers of the troposphere. This intrusion at the time when the cold front (Φ_x) passed through (which was observed in the south with a lag of 1 day, due to which the beginning of the period on the figure is shifted one rectangle to the right for this region) did not produce a marked cooling at the lower levels, where before this the temperature of the atmospheric layers had been reduced to the temperature of moderately cold weather in the process of effective radiation. Thus, at the lower levels, the intrusion of Arctic air was best expressed in cloudiness and precipitation, rather than temperature, conditions. In the mountain regions, however, this intrusion caused a sharp variation in the temperature characteristics of local weathers. This change was naturally greatest at those levels where the inversion effect was most pronounced before the intrusion. For example, at a height of 1.5 kilometers, in the mountain regions of the Trans-Ila and Dzhungar Ala-Tau, the sudden change of mean diurnal temperature when the cold [redacted] air intruded was about 10° (Medeo) and 5-10° (Kos-Agach), respectively. It is also interesting that the vertical distribution of local weathers at the initial moment of the Arctic intrusion was almost isothermal.

We now discuss the protective screening influence of the Dzhungar Ala Tau for fairly low cold intrusions. In the case under consideration, this influence was shown by the sharp lag in the passage of the cold wave into the Dzharkent region, which was observed here only on the 5th or 6th day of the period. This indicates that in our example penetration of the cold mass into the Ila River valley was quite slow. The frontal effect in precipitation and cloudiness was expressed here, as everywhere, as early as the second day of the period. The same phenomena, although not quite so sharply-defined, was observed for the Zaysan basin region.

Immediately following the cold intrusion, an anticyclone was formed in the Arctic air masses, the center of which remained persistently for 7 days over the central regions of Kazakhstan (D_1). Energetic cooling was observed in the very lowest tropospheric layers under conditions of such a rapidly-forming and persistent anticyclone. As a result of this, the local weathers in east Kazakhstan changed successively from the class of moderately cold weathers to quite cold, very cold (XIII), and even to severely cold weathers (XIV). The latter were observed only at separate stations (in B. Narymskiy and Kumashkin, for example) and lasted from 1 to 3 days. In the southern part of the region, the cooling was not so intense, and only quite cold weathers were observed.

On days when cooling was observed, the distribution of weathers with respect to height again was of the inversion type, which is well illustrated by the data of stations in [redacted] mountain systems of east Kazakhstan.

In regions where strong local winds develop intensively because of local geographical factors (Ayagus, Chubartau, Tansyk, Burlyu-Tyube and a number of other stations) and cause dynamic mixing, the cooling of the lower layers is noticeable weakened, and therefore very cold weathers are observed only on a few days when the force of the wind decreases in these regions.

In connection with the fact that the anticyclone center in the period under consideration remained stably over the central regions of Kazakhstan, the process of anticyclone settling had comparatively little influence upon the hydrothermal characteristics of local weathers. Its influence was felt slightly at the 1.3 kilometer level, where it was expressed by a sharp decrease of relative humidity for a slight temperature increase. At the end of the period, the anticyclone center shifted to Altay (D_2), due to which warming was observed over almost the entire territory. This warming in the beginning is explained by dynamic transformation of polar Siberian air which gradually changes into dynamically heated polar Siberain air, and later is even replaced by advection of polar Turan air, the influence of which remains possibly to the last day of the period (the structure of the process described is given at the bottom of Fig. 15).

In complex-dynamical climatological analysis, we must of course speak not of the analysis of one case, but of a number of such cases of Arctic intrusions, which we have done for east Kazakhstan. This naturally applies to other synoptic processes. We now show how conclusions were obtained which were useful in the dynamics of local weathers in a definite region by the examples of Semipalatinsk and Alma-Ata for Arctic intrusions of the winter period (December-February for 1938 to 1941).

We note first the high frequency of Arctic intrusions in the Semipalatinsk region in the winter period. Of the total number of Arctic intrusions in the Semipalatinsk region (21 cases) 8 cases included intrusions which did not reach the southern regions of east Kazakhstan. All the other cases of Arctic intrusions, being of different vertical extent, reached the mountain ranges of the Trans-Ila Alta-Tau and occupied the entire ter ritory of east Kazakhstan with the Arctic air mass.

In the physico-geographical conditions of the Semipalatinsk region (the region where the Irtysh River flows out onto the West Siberian plain), all Arctic intrusions (with rare exceptions) form quite cold weathers on the very first day. These quite cold weathers are most frequently accompanied by cloudiness, which gives precipitation (in the form of snow) in approximately half the cases. In these cases, local weather with a moderate but sometimes substantial wind is observed and the relative humidity varies from 81 to 90% and ~~more~~ less frequently from 61 to 80%. An Arctic intrusion under the conditions of the Semipalatinsk region is definitely cold in the lower layers only if the region was located in a warm P_T air mass before this intrusion. When this is the case, the temperature characteristics of the weather type drop sharply; i.e., the mean diurnal temperature drops not less than 5°, and sometimes even 10 to 15°. If, before the intrusion, the region was occupied by strongly cooled polar Siberian air, advection of Arctic air may not even be cold in the lower layers. There have been cases where intrusion of Arctic air caused a noticeable warming in the lower layers in the first period of intrusion.

In all cases discussed, the process of radiation transformation of cooling of Arctic air and its transition into polar Siberian air takes place from the beginning of the Arctic intrusion due to the development of anticyclogenesis. During this transformation, the dynamics of local weather are expressed in the sequential transition to weathers with lower temperatures. In some cases (quite rare, however), this change in the temperature characteristics of the lower levels is limited by the fact that quite cold weathers in their temperatures are close to very cold weathers. In other cases, the class of quite cold weathers changes quite rapidly into the class of very cold and occasionally into the class of severely cold weathers. Counterradiation of the atmosphere has exceptional influences upon the formation of local weathers in the winter. Severely cold weathers are impossible if the region was located in a warm Pt air mass before the intrusion; they are manifested in the radiation transformation of Arctic air into Polar Siberian air, but only when a local P_c air mass had already been cooled sufficiently in the lower layers before the intrusion of the Arctic mass. Obviously, under these conditions, counterradiation of the atmosphere is negligible, due to which the amount of effective radiation increases sharply, which intensifies the process of radiation transformation of cooling.

Thus, in the Semipalatinsk region, depending upon the conditions determining the temperature of thermal equilibrium, the process of radiation transformation of cooling Arctic air and transforming it into a local P_c air mass is limited by the establishment in the region, most often, of very cold, and, less often, severely cold weathers. This process takes place only so long as the anticyclone center remains over the central regions of Kazakhstan or close to Semipalatinsk.

The process of radiation transformation of cooling Arctic air and transforming it into P_c air in the Semipalatinsk region is sometimes replaced by the process of dynamic transformation of P air. The comparatively weak definition of the process of dynamic transformation of P_c air is explained by the proximity of the Semipalatinsk region to the centers of the influencing anticyclones. In the dynamics of local weather types, this is expressed by the fact that a slight ~~change~~ e temperature increase is observed with a simultaneous humidity drop (the humidity still remains within the limits 61-80%, however) after the cooling process in continuing clear weather. In other cases, the radiation transformation process is replaced simply by a restoration of heat advection or by a new influx of a fresh portion of Arctic air.

The duration of each of the ~~actual~~ periods ~~after~~ of actual intrusions considered was great and sometimes reached 15 days.

By generalizing the laws described in the dynamics of local weathers in the Semipalatinsk region for a period of intrusion of Arctic air and its subsequent transformation, we have constructed a diagram for the change of local weathers under these conditions (Fig. [illegible]). After the description of [illegible] figures, this diagram does not require special explanation; we point out only that in this diagram the break of the rectangle indicates that this weather class was maintained for several days).

The picture is quite different for the Alma-Ata region. As we have already pointed out, not all of the Arctic intrusions which are observed in the northern regions of east Kazakhstan reach the northern slopes of the Trans-Ili Ala-Tau; part of them, for purely dynamic reasons, do not reach the southern mountainous regions of east Kazakhstan; some others, having low vertical extent, are probably held back by the Chingis-Tau range. Not only are there fewer Arctic intrusions in the Alma-Ata region, but the duration of the intrusions is decreased. In our opinion, a geographical factor, the height of the area, also influence the lower frequency of Arctic intrusions in the Alma-Ata region. The location of the Alma-Ata Geophysical Observatory at 850 meters naturally results in the fact that some of the Arctic intrusions which reach the Trans-Ili Ala-Tau mountain chain may not cover the region of the city of Alma-Ata if they have small vertical extent and there is not dynamic head at orographic obstacles. However, without negating the real probability of such low Arctic intrusions, we do not think that why they are frequent in the Trans-Ili Ala-Tau region. Most often, the intrusions which reach east Kazakhstan have sufficient vertical extent to cover the Alma-Ata region.

All Arctic intrusions (with rare exceptions) in the Alma-Ata region appear as typically cold intrusions owing to the fact that the Arctic front in the southern part of east Kazakhstan usually divides the warm P_T air mass from the colder Arctic air mass. Thus, in the initial moment of the Arctic intrusion, due to the interchange of two sharply different air masses, the air temperature frequently drops sharply, so that the mean diurnal temperature decreases 5-10 or even 15°.

One might think that such diversity in the amount of sudden temperature change at the moment of Arctic intrusions is provided by the different thermal characteristics of the various cases pointed out of intrusions of Arctic air. Actually the Arctic intrusions themselves have ~~comparative~~ comparatively stable thermal character [illegible], so that in the first day of the period (with very irregular exceptions) moderately cold weathers [illegible] with complete cloudiness and, most often, precipitation. The differences noted in the contrast of temperatures between the first and second days of the period are due to the different degree of cooling of P_T air up until the Arctic intrusion occurs.

~~A tendency toward cooling is observed after the Arctic air mass enters the Alma-Ata~~

After the Arctic air mass enters the Alma-Ata region and the anticyclogenesis process is developed over Kazakhstan, a tendency toward further cooling is observed in the regions under conditions of clear and comparatively calm anticyclone weather. If this cooling develops, it frequently causes the mean diurnal air temperature to drop 5-10°, as a result of which the local weathers change from the class of moderately cold to the class of quite cold weathers (XI-XII). Very cold weathers are rarely observed here, and originate, in our opinion, only when a weak current is present from the colder neighboring lowland regions of East Kazakhstan, where radiation transformation of cooling Arctic air has already caused the formation of this class of weathers.

The process of radiation transformation of cooling of air is replaced in the Alma-Ata region, as it is everywhere in the mountainous southern regions of East Kazakhstan, by a quite sharply-defined process of dynamic transform ation. As a result of this, foehn-like effects in the form of a slight temperature increase for a simultaneous drop of relative humidity obtain development at the end of almost every period. The temperature increase is usually not more than 5° and rarely reaches 10°. The relative humidity may sometimes drop 40%. The change of local weathers toward warming as a result of the development of such intra-mass foehns does not go beyond moderately cold weathers, as a rule.

By generalizing the observations above on the formation of local weathers in the Alma-Ata region for periods of arctic intrusions, we obtain Fig. 18, which is similar to the one obtained for Semipalatinsk.

We have discussed the dynamics of local weathers in east Kazakhstan during Arctic intrusions in the winter in some detail in order to show the methods of investigating the formation processes of local weathers in complex-dynamic-climatological analysis. Since we do not have space to describe the genesis and subsequent development of local weathers during periods when other air masses and circulation types predominate in the same detail, we note only the following:

In winter, when a new cyclonic formation is influential, dynamic transformations may be replaced by heat advection, which in the mountainous regions of east Kazakhstan is accompanied by a sharply-defined foehn-like variations in local weathers but are not always foehns, strictly speaking. For short-period advection of a warm air mass, its influence is not always felt directly in narrow valleys and small basins covered by high mountains. The warm currents in this case pass over the dense and cold surface-air layers and leave the type of local weathers almost unchanged. During more intensive warm intrusions in the winter, the formation of warm weathers and weathers with advective thawing, sometimes accompanied by disappearance of the snow cover, is observed. The disappearance of the snow cover leads to a sharp heightening of the role of solar radiation in heating the lower layers of the troposphere due to the substantial decrease of the albedo. Warm weathers and weathers with thaws last for comparatively short periods in this region.

We used the same methods of investigation to analyze the formation of local weathers in east Kazakhstan in the summer. [illegible] are, however, the peculiarities present [illegible] methods of investigation. We therefore [illegible] of these peculiarities, both of [illegible] character.

1. In the latitudes of east Kazakhstan, we find high amounts of total radiation per unit of horizontal surface. Most of the total radiation is transformed into heat energy on the underlying surface, since the albedo of the underlying surface in summer is in general only 20-30% effective, and sometimes even less.

2. The accumulation of heat in the surface layers causes a regular and quite rapid heating of the lower atmospheric layers, which in this period are frequently in a state of unstable convective equilibrium. This [illegible] condition favors the development of ascending currents, but because of the fact that in many cases (because of various reasons) the condensation level is located considerably higher than the convection level, we do not observe resolution of the moist-labile state in the lower troposphere layers, and thus low-cloudiness or even clear weather lasts for a considerable period. The condensation level is frequently so high that even ascending currents developed in frontal processes cannot always reach this height, and therefore fronts often pass in this period without yielding cloud formation and precipitation.

3. Because of the continental nature of the climate of east Kazakhstan and also because of the fact that horizontal temperature gradients are negligible in the summer, the temperature contrasts of the different air masses

which enter east Kazakhstan are small. The temperature variation in connection with the passage of a front is therefore not as sharp as in winter.

4. The periods of time between the passage of two consecutive cyclonic formations is usually short and is frequently represented by diffuse pressure fields with negligible horizontal pressure gradients. The latter favors the development of intra-mass circulation processes, and thus any type of breeze currents are most sharply defined in this period.

Taking the above into consideration, we can state that in the summer demarcation of processes with respect to the different types of air masses [redacted] of little practical value because of the similarity of the [redacted] hygrothermal properties of [redacted] air masses. Subdivision of processes into intrusions, a) expressed by frontal cloudiness and precipitation and b) not expressed by cloudiness and precipitation, is more important. Under the conditions of east Kazakhstan, the first are most frequently cold fronts and the second, warm fronts.

Fronts expressed by cloudiness and precipitation produce sharp changes in local weather types and are accompanied by a temperature drop and a humidity increase, so that moderately dry and even drought dry weathers are frequently replaced. Thus, synoptic processes of this type are of first-rate importance for the agriculture of east Kazakhstan since they break the continuity of [redacted] dry periods.

After a front expressed by cloudiness and precipitation passes through, the formation of local weathers is dependent to a considerable degree upon the process of radiation transformation of heating. As a result of this process, a change from different types of non-dry to moderately dry and even drought weathers is observed in the dynamics of local weathers. During a period of radiation transformation of heating, the intra-mass process of resolution of the moist-labile state of the lower tropospheric layers may lead to the formation of weathers with diurnal cloudiness only when the condensation level lies below the convection level, which condition is not observed too often in the lowland regions of east Kazakhstan. The development of weathers with diurnal cloudiness in the intra-mass process does not interfere substantially with the subsequent formation of ~~drought~~ dry weathers in these regions, if, of course, the clouds do not produce precipitation. The formation of weathers with diurnal cloudiness and even of weathers with convective precipitation ~~becomes more~~ is more probable in the mountainous regions than in the lowland regions due to the marked rise of the condensation level over the former.

During periods of radiation transformation of heating, the role of local geographical factors in the formation of local weathers is not so sharply defined as in winter. Nonetheless, the influence of such factors as water systems and the height of the locale is still quite noticeable, in general preventing the formation of moderately-dry and dry weathers.

Fronts in which the condensation level is high, i.e., considerably above the convection level, do not produce a sudden change in local weathers in the summer and often do not interrupt dry periods. These frontal processes, being expressed only in the pressure and wind fields, do not even prevent in some cases the formation of severe droughts in the lowland regions of east Kazakhstan.

In our opinion, this type of analysis for a certain region puts a distinct genetic foundation beneath the idea of climate adopted in complex climatology. The structure of climate in weathers, which previously gave a purely static picture, becomes clearly dynamic after such an analysis.

In considering climate expressed in weathers, we become acquainted with not only the mechanical set of various weather classes, but also with the laws governing the transition from one weather class into another. These laws are basically dependent upon the actual geographical characteristics of the given region. All this is very useful for practical synoptic analysis in making weather forecasts for a region more exact as well as for pure climatological studies.

B. Study of the Dynamics of Local Weathers of Transformation Types and the Formation of Basic Types

The methods of complex-dynamic-climatological analysis are of special importance in the study of the formation and subsequent change of local weathers under conditions of transformation processes. This is because of the fact that the influence of the underlying surface upon the physical processes of the lower atmospheric layer is most clearly expressed in these periods. If the transition periods are sufficiently long in a certain region, we can find by the methods given the so-called fundamental types of weather. The concept of fundamental weather types was first introduced into complex climatology by Ye. Ye. Fedorov (1930), who also pointed out the methods for classification of these types.

Without violating the basic concepts of Ye. Ye. Fedorov on this problem, in recent years we have proposed to understand a fundamental type as a type of weather which emerges or [redacted] should emerge in a given geographical region as a result of a completed transformation of an air mass.

The proposed definition fully corresponds to that which was given by Ye. Ye. Fedorov. According to Fedorov, a fundamental type is an expression of the final result of "the [illegible] of [illegible] properties of an air mass with the influence of [illegible] [illegible] time, the new definition of a fundamental type makes the [illegible] classification more objective

Actually, it is well known that the final stage of transformation is characterized by an almost complete loss of the conservative properties which an air mass had obtained in the center of formation. Thus, it is just at this period that the influence of the landscape upon the physical properties of the air mass is most pronounced.

On the other hand, by noting that fundamental weather types emerge at the end of a transformation period, we topping off the process of degeneration of an air mass, we indicate a method for their classification. According to the contemporary ideas of dynamic meteorology, fundamental types are those weather types which are observed on days when the temperature of the lower layers of an air mass reaches the temperature of thermal equilibrium.

It should also be noted that fundamental types will often coincide with local weather types at certain periods of the year in certain geographical regions. This will be observed particularly where processes of radiation heat exchange are dominant.

In regions where periods of sharply defined transformations are observed comparatively rarely, the climatological importance of fundamental types is slight, and the usefulness of finding them becomes very doubtful.

Fundamental types were found for the European USSR by Fedorov separately for different physico-geographical zones (1937b).

Methods of complex-dynamic-climatological analysis were used for the lowland regions of Kazakhstan to determine the dynamics of local weathers in periods of air-mass transformations and to find fundamental weather types for winter and summer of three main landscape zones of this part of Kazakhstan (steppe, desert-steppe or semidesert and desert zones).

C. The Dependence of Local Weather Conditions Upon the Most Important Elements of the Underlying Surface

The first works on the analysis of the influence of the most important elements of the underlying surface upon the formation of local weather are credited to Ye. Ye. Fedorov (1923, 1929, 1935, etc). In many of his investigations, we find a complete treatment of the reasons for the formation of a certain type of local weathers under conditions of different landscape zones.

We should also mention the interesting and original work of Ya. I. Fel'dman on the analysis of the influence of woods and the snow cover upon the formation of local weather. This work is all the more unique in that its separate parts were done by different methods of climatological analysis.

The effect of woods upon the formation of local weathers in summer was analysed using the northern half of the European USSR as an example. Fel'dman clarified the influence of woods upon weather classes. The results of calculating the correlation coefficients for the degree of woodedness and summer weather classes permitted Fel'dman to establish a positive relationship of rainy and cloudy weathers with woodedness, a negative relationship of convective weathers with woodedness, and a quite indefinite relationship of precipitation with woodedness. Although the results of the investigation were interesting in themselves, the physical reasons for the relationships described are still almost unknown.

The effect of the snow cover upon local weather was studied from the same standpoint, but using methods of complex-dynamic-climatological analysis. This study showed that the process of formation of local weather in spring over the snow cover and outside of it is different in different air masses.

For example, when a cold air mass lies over a snow cover, then cold, low-cloudiness and windless weathers in which high diurnal air temperature amplitudes are observed are most frequent. Under the same cold air mass conditions, but outside the snow cover, weathers of a different type predominate. These are relatively warm, overcast or cloudy only in the daytime, with wind and with comparatively small diurnal temperature amplitudes.

When a warm air mass lies over a snow cover, weathers which are comparatively cold, cloudy or cloudy at night, with low diurnal temperature amplitudes, are observed in most cases. Outside the snow cover, however, warm weathers, low-cloudiness or cloudy at night, with high diurnal temperature amplitudes, are observed in most cases. No noticeable difference in wind is observed on the boundaries of the [redacted] snow cover.

In discussing weathers emerging in a local air mass along both sides of the snow boundary, [redacted] Fel'dman points out that there is a tendency towards smoothing of [redacted] differences in such components of the weather complex as cloudiness, wind, and diurnal temperature amplitude. At the same time, the difference in magnitudes of mean diurnal temperatures increase. The predominant weather type in both cases is low-cloudy weather with high temperature amplitude and moderate wind. Warmer weathers emerge outside the snow cover.

The difference mentioned in local weathers which are generated under identical circulation conditions but in some cases over a snow cover and in others outside of it are illustrated by Figs. 19 and 20, which we borrowed from the work of Ya. I. Fel'dman. These figures clearly show how important these differences, which are provided only by the characteristics of the underlying surface, may be.

Section IV - APPLIED COMPLEX CLIMATOLOGY

The methods of complex climatology are used in a number of works on climatic characteristics for the needs of farming, health resort studies, aviation, railroads, etc.

Applied complex climatological studies are broken up into two stages. The first stage of the studies has as its purpose the accurate ~~clarificatie~~ determination of the dependence of the given object of study upon weather conditions. In this stage are established the methodological approaches which will help to clearly reflect the importance of climate for the given object. Such approaches might include the selection of a certain set of meteorological elements and effects, the establishment of gradations in the scales of the later for drawing up a complex weather type, the choice of units of time for the complex type, the selection of a certain system for classifying types and subdividing them into classes, subclasses, etc. The second stage consists of applying the principles established in the first stage to the climates of various locales.

A. Use of the Principles of Complex Climatology in Agriculture

We now turn to works on climatic characteristics for agricultural needs. Much has been done in this direction by Fedorov and his coworkers, and therefore this account of the use of complex climatology in agriculture is essentially an acount of the use of Fedorov's complex method.

The first stage of these works includes studies to clarify the ~~importance~~ meaning of each weather type in Fedorov's classification for various farm crops. This meaning can be different and even opposite, first in various stages of the plant's development and, second, in various regions ~~in~~ depending upon their physico-geographical conditions. Up to the present, this type of work has been applied to the analysis of the speed of development and yield of cotton, wheat, sugar beets, corn, barley, and rice. Perennial observations at agricultural field stations were used as basic material for these works.

The method used in these studies follows:

The amount of harvest of a given type of crop per unit area is subdivided into the categories of outstanding, good, above average, average, poor harvest, and complete non-harvest. The weather types observed in the separate phases of development of the plant are examined with respect to each category. A catalog of weathers drawn up for the vegetation periods of all observations years is used for this purpose. Index cards of the weather catalog are selected for days corresponding to a definite phase of development of the plant. These are then sorted with respect to years with the different categories of harvests. The index cards of each such group are further separated according to weather type, and then the number of cases in it for each type is computed. This figure is entered in a table. We introduce here [Table 5] slightly abridged sample of ~~table~~ a table obtained by Fedorov in his studies of Poltavka wheat in a dry region of the Bezenchuk agricultural field station.

Table 5 illustrates the close relationship between the classified weather types and crop harvests and also the length of one of the phases of its development. As the table shows, days with complete drought not only were not observed for excellent and good harvests, but also were not observed for harvests of 39-58 poods per desyatina (2.70 acres). Incomplete droughts were observed for all harvests, but their frequency was clearly higher for poor harvests. The distribution of the number of days of moderately dry weather types shows a tendency, however, slight, towards poor harvests. Rainy weathers are clearly advantageous for the harvest; apparently, even a few days with rainy weahher are enough to produce a good harvest. Cloudy days without rain are less favorable, and low-cloudy non-dry still less favorable. The effect of weahher on the length of phase is the reverse of that described.

Such a close relationship between weather and harvests could not have been revealed by the method of average values. Nor could the temperature, humidity, cloudiness, or precipitation, taken separately, determine the quality of a harvest, since only their complex plays a decisive role in this case.

In order to proceed to the second stage of the study and characterize the climate of the [illegible] under study on the basis of the dependency revealed between weather and harvests, Fe[illegible] divided all the weather types with respect to favorability categories. For example, he divided the weather types listed in the preceding table into the following categories (for the "kushchen'ye-kolosheniye" phase in soft wheat): 1) rainy — very favorable; 2) cloudy without rain — favorable; 3) with diurnal cloudiness and low-cloudy non-dry — moderately favorable; 4) dry — unfavorable; 5) incomplete drought — harmful; 6) drought — very harmful; 7) complete drought — kills the harvest completely. For other phases, similar characteristics apply to other weather types.

After having defined which weather types belong to the various categories of favorability with respect to the different phases of development of the plant, we can without any difficulty divide the entire perennial set of weathers with respect to these categories.

By adding up the cards in each category [illegible] the [illegible] relationships from the numbers obtained, we can draw up a special table. Table 6 gives such quantitative [illegible] climatic characteristics [illegible] the vegetation season from the standpoint of favorability for the [illegible]

The ideas of complex climatology can also be applied usefully in [illegible] as, for example, in laboratory reproduction of meteorological processes ~~and, in particular~~, the Nichols method for laboratory reproduction of droughts. Analysis of drought as a meteorological complex, referred to a definite moment of the day, permits one to determine the [illegible] temperature and humidity conditions and [illegible] the wind velocity which [illegible] heat [illegible] for [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] nature in that [illegible] and also in that [illegible] the actual complex

B. Use of the Principles of Complex Climatology in Medicine

Since effective temperature (the heat sensation of a human) is a function of temperature, humidity, and wind velocity, these can change within wide limits without changing the heat sensitivity of a person. It remains the same for such widely divergent combinations of the meteorological elements as

Temperature	Relative Humidity (%'s)	Wind Velocity (m./sec)
17.8	100	0
28.6	20	2.0

This extremely important fact can be used to explain why the high temperatures of the Middle-Asiatic deserts are borne comparatively easy by man under drought weather conditions when even slight breezes are blowing.

Great importance has been attached to the study of effective temperatures by several researchers. V. A. Yakovenko (1928) pointed out that an attempt to evaluate the influence of a fourth factor, solar radiation, could be found in the works of Missenard, who suggested a new index for the heat sensitivity of man, namely the resultant temperature. The resultant temperature expresses in one number the complex influence of all four factors, i.e., temperature, humidity, wind velocity, and solar radiation.

This index of the heat sensitivity of man also began to find use applied to the climatic characteristics of health resorts. One study along these lines was that made by V. A. Yakovenko in [redacted] 1941 in the "Oniponkp" health resort. Study of the resultant temperature conditions in the above resort permitted V. V. Shiba to draw up a diagram of the heat sensitivity of persons taking sunbaths and thus clarify the comfort zone. In Yakovenko's opinion, 16° and 1[illegible]° resultant temperatures should be taken as the lower and upper limits, respectively, [illegible] comfort zone [illegible] these resultant temperatures, [illegible] the persons [illegible] felt normally comfortable. It was also recommended that [illegible] comfort zone, since more than [illegible] uncomfortable under these conditions.

No final conclusions [illegible] made as yet regarding the physiological value of resultant temperatures revealed only by interrogation. Along with the positive evaluation of this index of heat sensitivity given by several authors, we also find different outlooks on this problem. For example, A. N. Boyko wrote in 1927: "We should reject attempts to create a new [illegible] of effective temperatures based upon the addition of solar radiation as a fourth factor. Actually, not one, but a whole ser[illegible] be added, i. e., radiation, [illegible] sunbath (general or [illegible]) etc.".

The arguments against [illegible] fourth fact[illegible] effective temperatures seem [illegible] the results of a number of observations by Profes[illegible] and [illegible] co-workers in the meteorological chamber of the Institute for Labor Hygiene and Occupational Diseases. By studying the reaction of persons to cooling the walls of the chamber while holding the temperature and wind velocity constant and then simultaneously cooling the walls while increasing the temperature, Letavet established: 1) that the heat sensitivity of the persons tested for the same temperature and wind velocity between the persons tested and the wall was directly dependent upon the cooling (negative radiation) of the walls; 2) when the temperature of the air passing between the persons tested and the cooled walls was increased, not only did the feeling of warmth decrease, but the skin temperature and even the intramuscular temperatures decreased as well.

In concluding this short summary of works on the complex effect of 3 or 4 meteorological factors upon the human organism, we still must discuss how the ideas described are connected with the methods of complex climatolgical descriptions. From the above, it is obvious that in medicinal meteorology and climatology the quantities effective, equivalent-effective, and resultant tempeature express some definite heat sensation of man under the influence of meteorolagical complexes, i.e., weather types, consisting, respectivity, of two (temperature and humidity), three,(temperasure, humidity, and wind), and four (temperature, humidity, wind, and solar radiation) elements. The magnitude of a certain index expresses only the definite heat sensation of man which is established under the influence of some weather type, but does not and can not reveal the structure of the weather type to which it corresponds. Actually, it is practically impossible to find a single-valued magnitude of effective, equivalent-effective, or resultant temperature to correspond to each definite weather type as they are understood in complex climatology, where they are determined by the composition of the meteorological elements and their gradations. This magnitude can only be calculated by using the primary data of meteorological observations and additional reports which clarify the characteristics of the given weather cases

In the same way, if only one value of the effective temperature or another index of heat sensation is known, we cannot say accurately the weather type to which this value corresponds.

Thus, we consider that it is more useful to give a climatological description of resorts as it is usually done in complex climatology, by introducing only the quantity effective, equivalent-effective, resultant, [illegible] other calculated temperature [illegible], for example, Sheleykhovskiy's [illegible] weather types (the weather of a day or of the time of observation).

[illegible] Use of the [illegible] of Complex Climatology in Transportation

[illegible] of ideas developed by the school of complex climatology [illegible] works applied to the requirements of railroad transportation. [illegible] of this type of work [illegible] done by N. I. Bel'skiy and [illegible]. This work was done by the authors for the railway [illegible] bears the features of an applied climatological description. The work is divided into two parts, climatological and synoptic, both carried out completely independently and outwardly showing no relationship to one another.

The first part, the climatological description of the region under study, contains, along with a general physico-geographical description of the region and a short description of the [illegible], a section in which the author uses a complex consisting [illegible] three meteorological elements, namely temperature, wind velocity and precipitation, to characterize the [illegible] as a basis for delineating [illegible] and "drift ness". [illegible] were [illegible] evaluations. The [illegible] wind, numerically [illegible] by the sum of the numerical evaluations of these elements defined, according to the author, the [illegible], the sum of three numerical evaluations, temperature, wind, and precipitation, defines the "bleakness" of the weather, and this sum is increased by one unit if a snowstorm is observed. "Drifty" is considered a day in which a snowstorm is observed and also a day with snowfall of at least 2 millimeters precipitation.

As a result of the analysis, the frequency of these weather types in the region under study was derived. Unfortunately, this frequency is in no way connected with the frequency of synoptic types of snowstorms which is given in the second part of the work.

In our opinion, the complexes selected to determine "coldness", "bleakness", and "driftiness" are useful in practice although highly arbitrary. In any case, we should not pass by this first curious attempt to use the ideas of complex climatology in such descriptions.

D. Use of the Principles of Complex Climatology in Aviation

The importance of weather types for the work of aviation is now beyond question. For example, A. A. Kulakov and V. A. Shtal' (1940) pointed out that "the work of aviation depends upon combinations of a number of meteorological elements (i.e., a weather types), which influence it simultaneously at a given moment".

This also determines to a considerable degree the tasks of aviation climatology, i.e., to give exhaustive information on the probability of weather types of varying degrees of flying difficulty for a certain region in a certain period. Climatological data of this type permits one to select the time and the route of flight which are least likely to be cancelled because of weather conditions.

Thus, if we consider that the main task of any aviation climatological description is to establish the frequencies of "flying" and "non-flying" weather types for a certain region for different periods of the year and day and also to clarify processes leading to the formation and subsequent change of these weather types, the usefulness of methods of complex climatology for these purposes becomes apparent.

The application of these methods to the special purpose of investigating the climate of localities on air routes requires extensive revision of the composition of the weather complex. We must include in the weather complex used all those meteorological elements and phenomena which exert the greatest influence on the flight of airplanes. Then, from the weather complex for whole days, we must changeover to the use of the weather of a moment in order to gain an idea of the frequency of various weather types at different times of the year and day.

The first experiment [illegible] the climates of regions of [illegible] He suggested [illegible] ness, visibility, wind [illegible] which are most important for [illegible] weather complex of elements and phenomena were selected so that the frequency of weather types of various degree of flying difficulty could be evaluated both for takeoff and landing of planes and for their technical exploitation on the ground.

It seemed efficient at that time in describing the climates of airports to distinguish the elements and phenomena mentioned above by the following gradations:

1. Wind: wind direction with respect to 16 points of the compass; wind velocity in the intervals: calm, 1-5 m/sec, 6-10 m/sec, 11-15 m/sec; 16-20 m/sec; above 20 m/sec.
2. Air temperature: from -5 to 0° C; from 5° to 0° C, and from there on in steps of 10° for both positive and negative temperatures.
3. Cloudiness: amount of low-level cloudiness in the intervals 0-1, 2-5, 6-8, and 9-10; height of lower boundary of clouds - below 100 meters, 100-200 m, 200-500 m, 500-1000 m, 1000-2000 m, and above 2000 m.
4. Visibility: horizontal visibility less than 0.5 km, 0.5-1.5 km, 1.5-5.0 km, 5-10 km, above 10 km; phenomena ~~[illegible]~~ reducing visibility (smoke, fog, sleet, rain, snowfall, rain squalls), and thunderstorm phenomena.

The use of such a weather complex and the application in the future of special letter formulas and the method of a catalog of weathers will clarify the climatic features of the region under study through the frequency of various types of aviation weathers at various times of day throughout the year. Calculation of the probability of "flying" and "non-flying" weathers for a certain airport which would be suitable for various machines would give, in our opinion, very useful material for planning the schedules of mail and passenger routes.

We should point out here that the method of analysis just discussed can be used successfully in the climatological description of limited regions of operation of agricultural ~~aviation~~ which uses chemical substances [illegible] to fight pests. All that is necessary in this case is to substantially decrease the wind velocity gradations to isolated groups of winds velocities: calm, and winds with forces 1, 2, and 3. As for the rest, the weather complex and the entire plan of climatological analysis used can be left without change. N. V. Sagatovskiy's work of 1943 describes these "chemical" weather types.

By using the experience of preceding works in the field of complex climatology in general and the experience of using the complex method for the ~~climatolo-~~ climatic description of airport regions in particular, [illegible] Gal'tsov made an important advance in the development of this method. He introduced methods of complex climatology into the practice of climatological description of air routes.

We will consider briefly the innovation introduced by this researcher in the development of ideas of the school of complex climatology.

When a researcher attempts to perfect the method of climatological description, not of the regions of individual airports, but of air routes, he must expand the spatial boundary of the weather type, keeping in mind "aviation" weather. The spatial boundaries of "aviation" weather are ~~not~~ very vague. First, [illegible] not [illegible] limited to the surface layer but includes all layers up to the airplane's ceiling. Second, "aviation" weather covers an atmospheric state far beyond the range of vision of a single observer and includes simultaneously observed meteorological conditions within the entire "flying area" Thus, the concept of "aviation" weather is basically different from that of "local" weather and comes closer to the concept of "synoptic" weather.

The elements of the meteorological complex characterizing "aviation" weather are: 1) visibility conditions, determined by the spatial position of zones of clouds and fog; 2) [redacted] icing conditions, 3) wind direction and velocity at various levels; 4) atmospheric electrical discharges (thunderstorms), 5) remous ("local atmospheric disturbances") 6) the presence of solid particles in the atmosphere (hail, sand, etc); 7) change of pressure along the flight route; 8) [redacted] air temperature; and 9) state of airport surfaces. The state of the above elements and phenomena throughout the "flying space" determines the types of aviation weather. The [redacted] "flying space" is that space which is bounded above by the [redacted] ceiling of the plane, in length by the range of flight, and in width by the possible deviation of the plane from the axis of the route.

In determining "flying" and "non-flying" weather, Gal'tsov conditionally classified 4 types of weather for which the most important of the characteristics above are so intense or so distributed in the flying space that a regularly scheduled flight is impossible. The characteristics of these types follow:

Type 1 _ (conventional designation - H_1). This weather is "non-flying" for all types of flights. It can be caused by such reasons as: a) cloudiness with a lower boundary below 200 meters at one of the terminal airports of the route; b) visibility less than 2 kilometers at one of the terminal airports; or c) a zone of icing, sleet, sandstorm or thunderstorm at any point of the route, when these zones cannot be avoided.

Type 2 (conventional designation - H_2). This weather is "non-flying" only for passenger planes having complete radio-navigation equipment, and also for planes serving other purposes (mail, etc), not having such equipment. This type of "non-flying" weather can be caused by: a) cloudiness below 200 meters on an intermediate part of the route, crossing of which takes more than 2 or 3 hours (length of the section about 500 kilometers), or b) visibility less than 2 kilometers in a similar stretch.

Type 3 (conventional designation - H_3). This weather is "non-flying" only for airplanes not having radio-navigation equipment. This type of weather is characterized by cloudiness below 200 meters or visibility less than 2 kilometers on any intermediate section of the route of less than 500 kilometers length.

Type 4 (conventional designation - L). This weather is "flying" for all types of flights. A characteristic of this weather type is the absence of cloudiness below 200 meters and visibility less than 2 kilometers at any point of the route.

These are the types of aviation weathers which are of practical importance for determining the flying conditions for the routes.

In order to determine the importance of each weather type in the formation of the climate of the route under study, A. P. Gal'tsov, in conformance with methods of complex climatology, suggested the following arrangement for processing the data of meteorological observations. The results of observations for each definite period from all stations located along the route and within 100 kilometers from the axis of the route, are recorded the usual methods in synoptic meteorology on a special card (Fig. 21). This card contains the name of the air mass covering the region of the route, indicates the position of the fronts influencing the weather of the route, and also takes note of pressure conditions (the circulation type). These cards, drawn up for each day and each period, make up a catalog of "aviation" weathers.

By analysing each of the cards and noting on it the weather type (№1, №2, etc), we can easily compute the frequency of each of the four weather types and thus establish the probability of non-flying weather conditions for a certain class of flights.

To illustrate, we show a diagram of the frequency of flying and non-flying weathers for one of the USSR air routes (Fig. 22). This figure compares exploitation conditions of two sections of the route (Gal'tsov and Chubukov, 1940).

In addition, this system of cards permits us to clarify in detail the importance of various meteorological factors and their complexes in the formation of various types of "aviation" weathers. The system makes its possible to determine the type of distribution of these factors in the "flying space" and also the effect upon their behavior of characteristics of the underlying surface of separate sections of the route.

Section V - THE PROBLEM OF CRITICISM OF COMPLEX CLIMATOLOGY

From what has been said, we can gain some idea of the completeness and scope of the studies completed. We can now state that, primarily by the works of Ye. Ye. Fedorov and his followers, a new climatological school, called complex climatology, has been created and developed in the USSR.

In complex climatology, climate is considered as a complex combination of weathers, studied with the help of frequency of weathers of certain types. The main methods developed for this type of climatological analysis are essentially different from those established in the so-called classical climatology. The ideas developed in works on complex climatology [redacted] have generally been warmly received in scientific circles of the Soviet Union. Climatology courses taught in hydrometeorological institutes and technical schools have recently ~~devote~~ been devoting many hours to the theory and practice of complex climatology and personnel of scientific-research organizations of various offices have more and more been resorting to methods of complex climatology in [redacted] climatological analysis. The last statement is well illustrated by the bibliography of this work.

However, in the first years of development of complex climatology in the USSR, the works of Fedorov were met with skepticism and even opposition by individual representatives of the old climatology. But we consider this period only as a stage of vexing interferences which had no basis. In recent year, a general positive evaluation of complex climatology even on the part of respresentatives of classical climatology is [redacted] characteristice. Thus, in T. V. Pokrovskaya's work (1938), we find a very sympathetic report on Fedorov's method. Discussing experiments in classification of weathers, she wrote: "The most persistent advocate of the idea of classification of weathers is Fedorov, who had coded the weathers in dependence upon the values of their separate elements. This method has been successfully used by its author in many practical problems of aviation and agriculture".

Of course, we cannot say that at present there is no serious criticism of complex climatology, but there is little and all of it essentially reduces boils down to two points.

The most important is the reproach, to all researchers using methods of complex climatology, that the classification of weathers used in these methods suffers from extreme formalism. This criticism was frequently advanced [illegible] appeared [illegible] investigations [illegible] researchers [illegible] stem of applied complex [illegible] because the method of weather classification [illegible] has changed flexibly with the object of study [illegible] now we can definitely state that it is impossible to devise a universal system for classification of weather which would apply with equal force to agriculture, transportation, medicine, and aviation. Thus, in any complex climatological study of an applied nature, the only thing that remains unchanged is the basic principle of complex climatology; i.e., the expression of climate through weathers. The weather types with which the climatologist must become familiar will change both in the makeup of meteorological elements and in the gradations selected for them. In addition, the weather type in some cases will apply to whole days and in others only to a definite moment. Thus, the criticism of formalism in classification of weathers is unfounded from the standpoint of applied complex climatology.

Now, let us consider the same criticism of formalism in the classification of weathers from the standpoint of theoretical climatology. Some critics consider that the method of classification of weathers proposed by Fedorov cannot be used for studies in dynamic climatology, since a fixed scale for gradations of the meteorological elements is used in this method. This apparently would lead to conditional and formal formation of various weather types which would not be connected with the natural characteristics of dynamic meteorological processes. This type of criticism is found, for example, in a course on climatology by four authors (Alisov et al, 1940), where in the chapter on "Complex Characteristics of Climate", we find: "Thus, Ye. Ye. Fedorov beforehand sets gradations of the elements for relating each day to some certain type. It would be possible to change the gradations so accepted without changing anything in essence. In connecting the frequency of the various complexes with respect to groups, various approaches are possible in dependence upon the practical and theoretical purposes established. This has meaning in solving individual problems, but for the general characteristics of climate at the present time we need another approach based upon the classification of physical types of weather, and only after this can we calculate numerical characteristics of the types so-classified."

If we considered this remark correct, we would have to acknowledge the possibility of using a moveable scale in classification of weather to select the gradations of the meteorological elements entering into the weather type. This would be necessary because one and the same atmospheric process has different regimes of the meteorological elements in different physico-geographical zones. This is demonstrated by the fact that one and the same air mass has different characteristics of the conservative properties in different geographical regions. Moreover, one and the same atmospheric process which is repeated many times in the same region does not have strictly single-valued numerical characteristics.

However, the introduction of moveable scales into climatological analysis for the numerical characteristics of the meteorological elements for a complex description would make this method so difficult that it could have no practical application.

But what some consider a major defect in the complex method is considered by others to be its exclusive feature of merit. For example, M. Ye. Podtyagin in discussing Fedorov's method at one of the sessions of the Scientific Council of the Alma-Ata Geophysical Observatory took note of the complete objectivity of the method of classification of weathers. No matter how different in their nature are atmospheric processes observed in different geographical regions, they obtain quite clear characteristics in a weather type, the structure of which is definite and admits of no subjective interpretations. This method of climatological analysis is the only one which can be used ~~in compared~~ for the comparative complex climatological characteristics of different regions of the earth.

In addition, as we have pointed out previously, the idea of complex climatology is not in contradiction to the newest ideas of the characteristics of atmospheric processes ~~and~~ but rather makes it possible to express these characteristics through weather types. This is clearly shown in works on the development of complex-dynamico-climatological analysis.

Another charge which has been leveled against the use of the complex method is that the latter is so difficult technically that its use on a large scale is impossible. There is some justice to this charge, of course. The drawing up of complex characteristics assumes the use of a card catalog of weathers, which must be written for each of the stations used for a number of years. Thus, ~~the~~ considerably more labor is involved in this method than in the method of analysis of the individual elements. But even this argument has lost force recently because of the ever-increasing large-scale use of calculating machines in the practice of climatological and hydrological calculations made by meteorological services. The technique of such machine processing requires a certain type of weather catalog, ~~the~~ in which the most important data of meteorological observations of the station for the given day are set out in a special way on cards of this catalog.

The compilation of such a special weather catalog in the future will permit a case of certain complex to be selected rapidly in machine processing. Thus, the last argument agains the use of the complex method in the future is eliminated by technical progess in methods of statistical processing of data from meteorological observations.

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KEYS TO FIGURES

Section VII - Figures from the Book

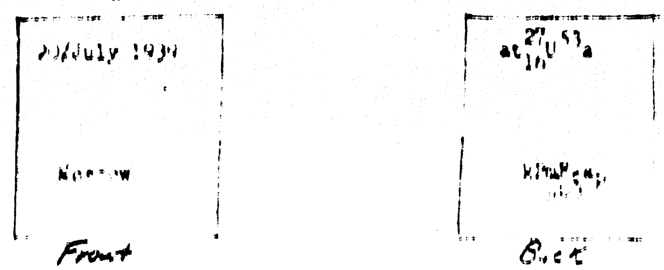

Fig. 1. [illegible] of a card in the weather [illegible] – p 17 (text)

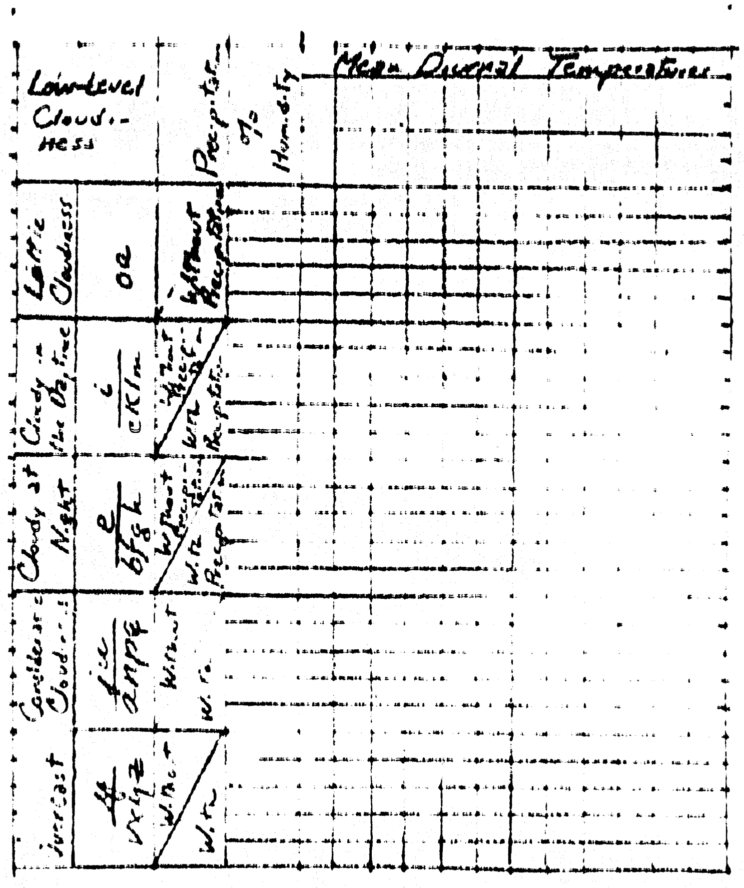

Fig. 2. Weathers Without Frosts and Weathers With Frosts and Thaws for wind in the daytime; = for a note "thaw" on cards – p [illegible] (text)

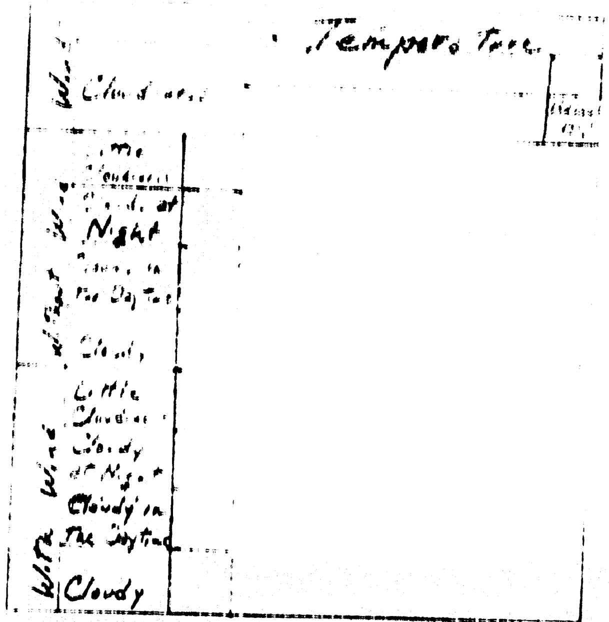

Fig. 3. Freezing Weathers p. 24 (text)

p 25 (text)

Fig. 4. Conventional Designations for Figures Nos 2, 3, 5, 6, 7, 8, 9, 12, 13, 14

1, Drought-Dry Weathers, 2, Maderately Dry; 3, Low-Cloudy; 4, Cloudy in the Daytime Without Precipitation; 5, Cloudy in the Day with Precipitation; 6, Cloudy at Night Without Precipitation; 7, Cloudy at Night with Precipitation; 8, Cloudy Without Precipitation; 9, Rainy; 10, Damp-Tropic; 11, Cloudy with a Transition Through 0°; 12, With Radiation Thaw (or with Frost at Night; 13, Slightly Cold; 14, Moderately Cold Without Wind; 15, Moderately Cold With Wind; 16, Quite Cold Without Wind; 17, Quite Cold With Wind; 18, Very Cold Without Wind; 19, Very Cold With Wind; 20, Severely Cold Without Wind; 21, Severely Cold With Wind; 22, Extremely Cold Without Wind; 23, Extremely Cold With Wind; 24, Boundaries With Res ect to Temperature (in 10° intervals); 25, Weathers Which were not Observed.

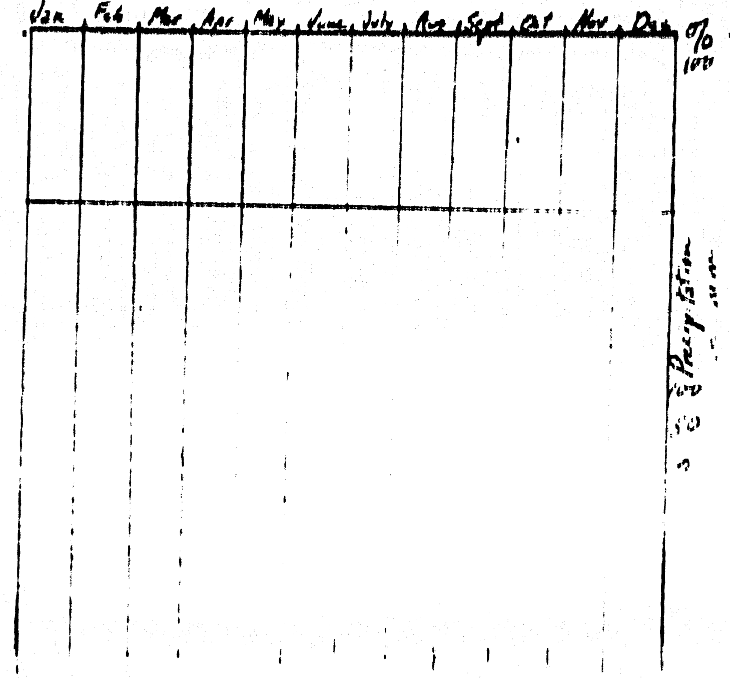

Fig. 5. Structure of the Climate of Moscow in Weathers p. 27

1 = Absolute Air Temperature Maxima; 2 = Mean Monthly Air Temperatures; 3 = Absolute Air Temperature Minima

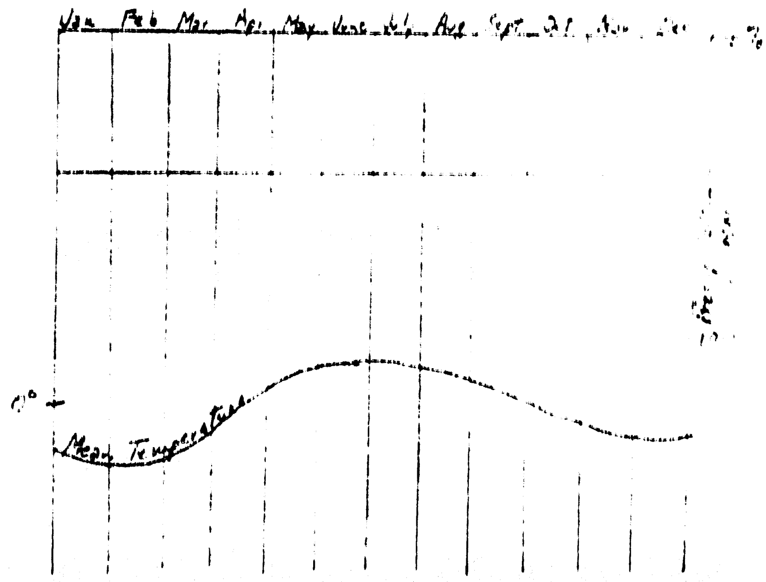

Fig. 6. Structure of the Climate of Ural'sk in Weathers p. 28

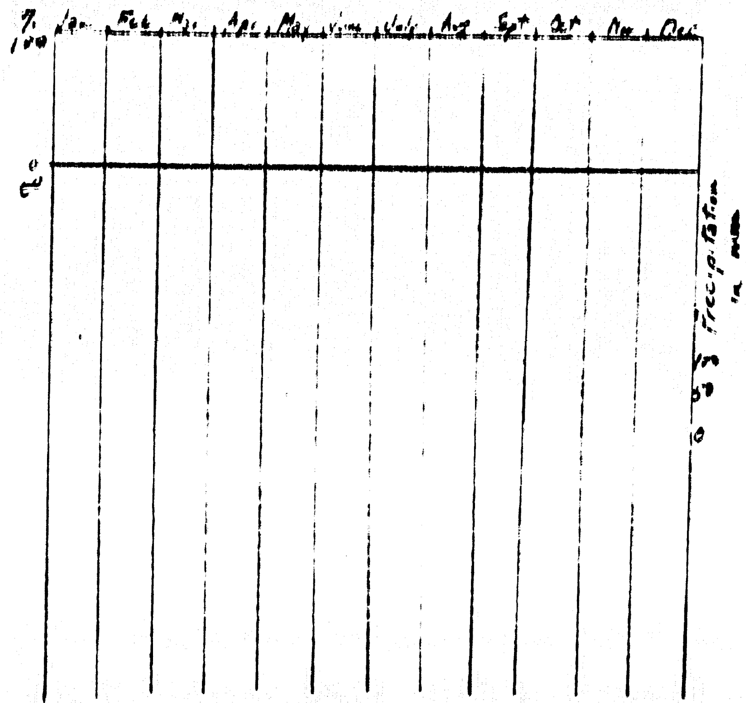

Fig. 7. Structure of the Climate of Kzyl-Orda in Weathers p. 29 (Text)

1 - Absolute Air Temperature Minima; 2 - Mean Monthly Air Temperatures; 3 - Absolute Air Temperature Minima

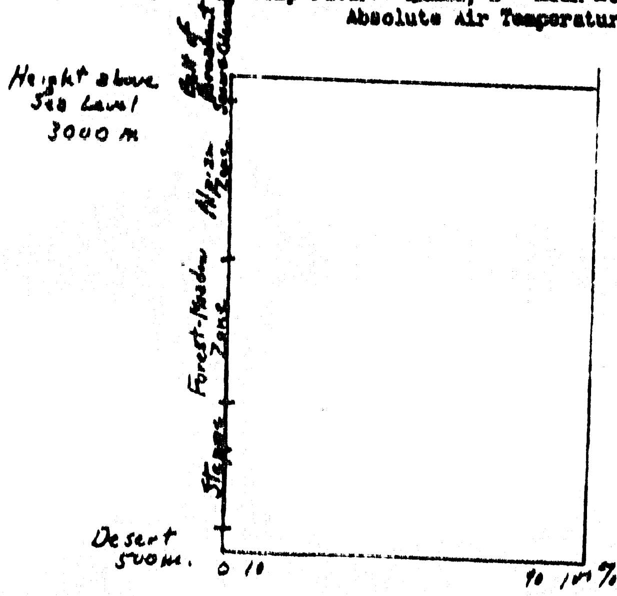

Fig. 8. Vertical Zonality of Weathers in One of the Southern City Regions in July p. 32 (Text)

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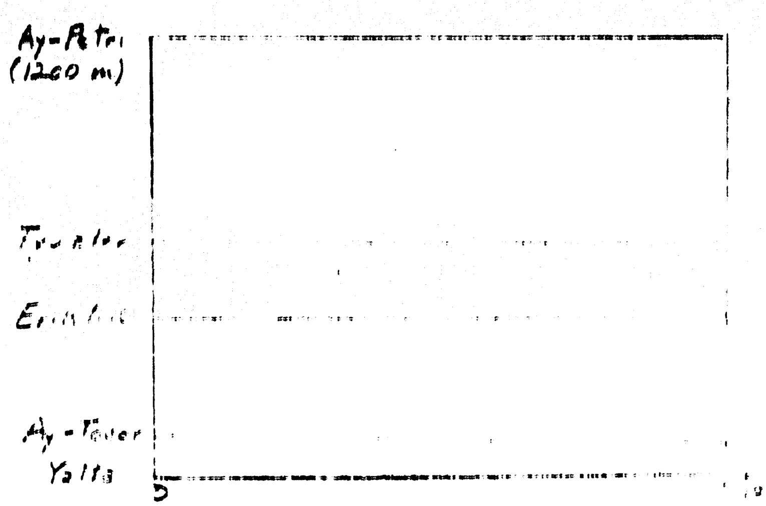

Fig. 9. Vert[illegible] of [illegible] slope of the Crimean Mountains in July p. 33 (text)

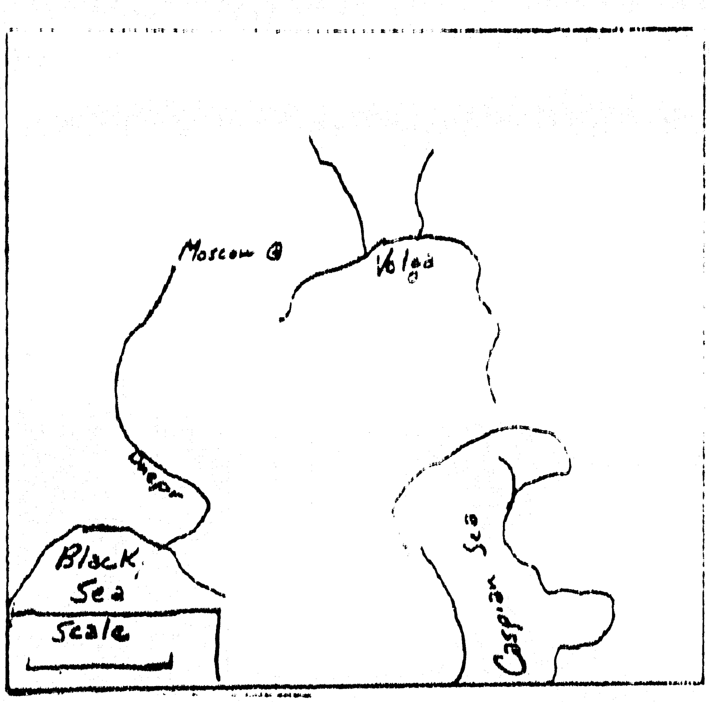

Fig. 10. Distribution of Frequency (in number of days) of Drought-Dry Weathers for the European USSR in July (according to Ye. Ye. Fedorov) p. 35 (text)

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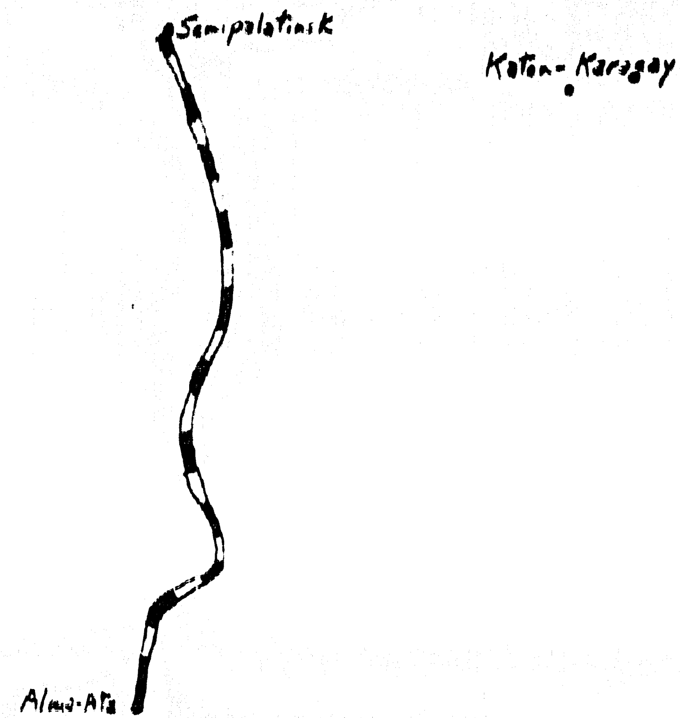


Fig. 11. Distribution of Frequency (in %'s) of Drought-Dry Weathers for the eastern Kazakhstan in July p. 36 (Text)

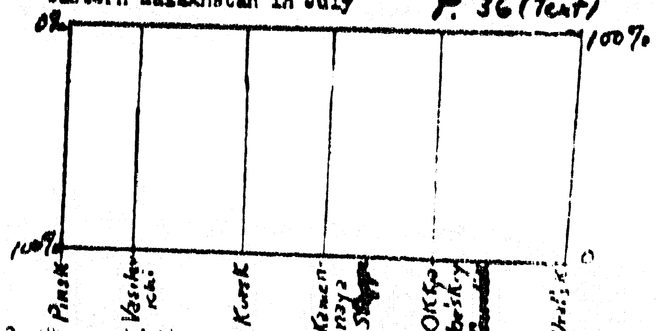


Fig. 12. Change [illegible] the structure of climate in weathers in [illegible] along the 52nd Parallel (European USSR, according to data from [illegible]) p. 37 (Text)

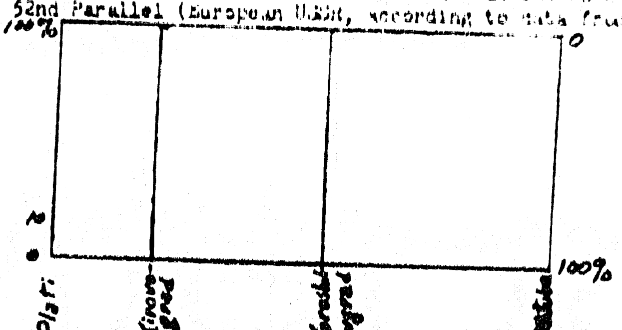


Fig. 13. Change of the Structure of Climate in Weathers in July Along the 48th Parallel (European USSR, according to data from 1898-1917) p. 37 (Text)

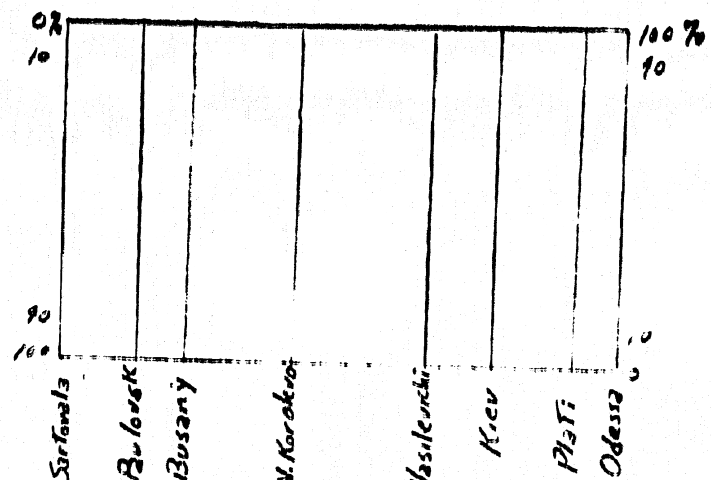


Fig. 14. Change of the structure of climate to weathers in July along the 50th Parallel (European USSR) according to data of: 18[illegible]–1917) p. 38 (text)

Name of Station	Day of Month	12	13	21
	Day of Period	1	2	10
Semipalatinsk				
Ust'-Kamenogorsk				
Ridder				
Zyryanovsk				
N. Narymskoye				
Katon-Karagay				
Buran				
Zaysan				
Kumashkino				
Kokpekty				
Zhangiz-Tobe				
Zharma				
Dyagus				
Chubartau				
Tansyk				
Burlyu-Tyube				
Matay				
Bakhty				
Sarkand				
Taldy-Kurgan				
Kos-Agach				
Kugaly				
Dzharkent				
Chilik				
Podgornoye				

$$P_T - F_C - A \text{ ——— } A - P_C \text{ ——— } P_C$$
$$P_T - F_C - A \text{ —— } A - P_C \text{ ——— } P_C$$
$$\text{——— } D_1 \text{ ——— } D_2$$

Fig. 15. The Dynamics of Local Weathers For an Intrusion of Arctic Air With a Subsequent Transformation of It into Polar (from 12 to 21 Jan. 194 1939). p. 43 (text)

Name of Station	Day of Month	13	14	21
	Day of Period	2	3	10

Uyn-Uchi [illegible]

Verkhniy Gornel'nik

[illegible] Gornel'nik

Ma [illegible]

[illegible]
[illegible]

New airport

[illegible]

Fig. 16. Th[illegible]
[illegible]
[illegible] p. 44 (Text)

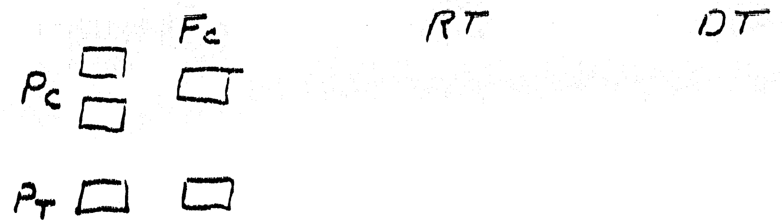


Fig. 17. Diagram of the Dynamics of Local Weathers [illegible]
Intrusions in the [illegible] Region p. 51 (Text).

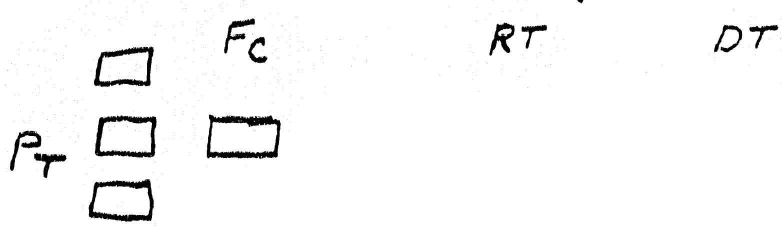
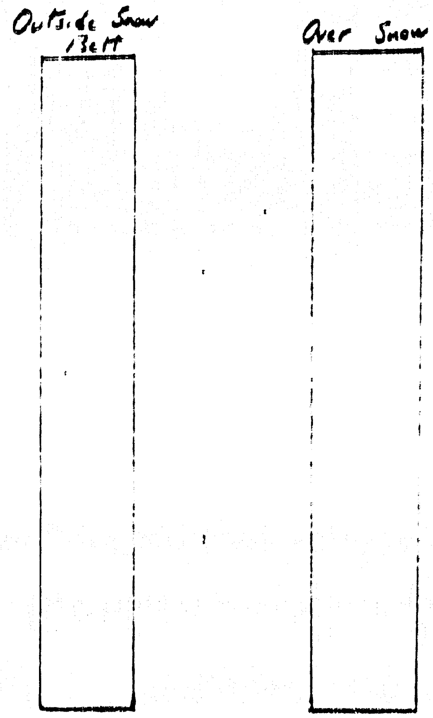


Fig. 18. Diagram of the Dynamics of Local Weathers in A Period of Arctic
Intrusions in the Alma-Ata Region p. 53 (Text)



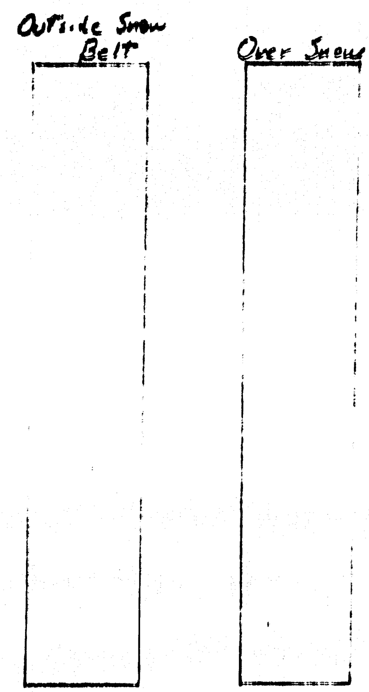


Fig. 19. Frequency of Weather Types in a Warm Air Mass (2nd half of March)

Fig. 20. Frequency of Weather Types in a Cold Air Mass (1st half of April)

Key to Figs. 19 and 20 - Slating Cross-Hatching,-Cloudiness High and Gay, Vertical Hatching, Cloudiness in the Daytime; Square Cross-Hatching, Cloudiness at Night; Without Hatching, Low-Cloudy Weather; One Vertical Opening, Temperature is Higher by One Gradation (5°) In Comparison with the Lowest Temperature Observed in the Given Air Mass; Two Vertical Openings, Temperature is Higher by Two Gradations (10°), Arrow, Weather with Wind

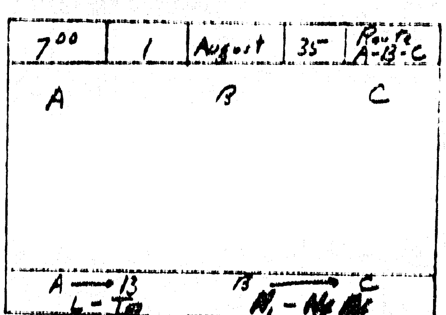


Fig. 21. Sample of a Card in the Catalog of Aviation Weathers; Tg, Ground Fog; Nf, Low Cloudiness; Rf, Frontal Rain

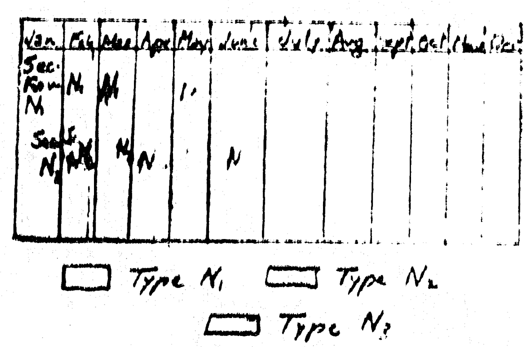


Fig. 22. Comparison of Exploitation Conditions of Two Parts of a Route

KEYS TO THE TABLES

[illegible] 1

1. [illegible]

2. Relative [illegible]

3. [illegible]

4. Quantity of [illegible] (in mm

5. [illegible]

6. [illegible]

7. Atmospheric phenomena

8. Types of weather

9. Note. The amplitude of temperature in weather type is taken between the temperature at 1300 (1 PM) and the minimum

10. Conditional designations of atmospheric phenomena

11. Fog

12. Downpour

13. Dew

14. Rain

15. Snow cover

16. Snow pellets

17. Snow

18. Weak indication of rain

KEY

Table 2.

1. Weather types and their repetition Station: Timiryazev Academy, Moscow

N.Lat 55°50', E.Long 37°33'

Height = 167 m

Month: May

Years: 1898-1917

2. Cloudiness

3. Average daily relative moisture of the air (%)

4. Wind

5. Quiet

6. In the daytime

7. Moderate

8. Strong

9. Temperature in °C

10. Without precipitation

11. Small cloudiness

Cloudy at night

Clear in the daytime

Clear at night

Cloudy in the daytime

Considerable cloudiness

Cloudy, overcast

12. With precipitation

13. Cloudy at night

Clear in the daytime

Clear at night

Cloudy in the daytime

Considerable cloudiness

Cloudy, overcast

KEY

Table 3.

1. Conditional number of the class

2. Nos. in the legend (Figure 4)

3. Nomenclature of the class of weather

4. Arid — Dry-arid * ; Moderate-arid

*Note: for certain purposes it will be useful to divide the class of dry-arid weather into complete and incomplete dries

5. Hot not Dry — Slightly moist

   Cloudy in the day — without precipitation; with precipitation

   Cloudy at night — without precipitation; with precipitation

   Cloudy without precipitation

   Rainy

   Moist-Tropical

6. Thaw — Cloudy with transition through 0°; Radiative thaw (or frost at night)

7. Frost — Weak

   Moderate — without wind; with wind

   Considerable — without wind; with wind

   Strong — without wind; with wind

   Severe — without wind; with wind

   Extreme — without wind; with wind

KEY

Table 1.

1. Repetition of classes of weather near Moscow

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Cloudy at night [illegible]
[illegible]

Cloudy, overcast

Rainy

Cloudy with transition through 0°

With radiative thaw

Slight frost

Moderate frost	without wind with wind
Considerable frost	without wind with wind
Strong frost	without wind with wind
Severe frost	without wind with wind
Extreme frost	without wind with wind

KEY

Table 5.

1. The connection of the crop yield and duration of the seeding-earing phase of wheat with weather.
2. Types of weather
3. Crop yield (in poods per desyatina (= 2.70 acres)
4. Duration of the phase (in days)
5. (a) Complete drought

   (b) Incomplete drought

   (c) Moderately dry

   (d) With daytime cloudiness

   (e) Slightly cloudy, non-dry

   (f) Cloudy without rain

   (g) Rainy

KEY

Table 6.

1. Percent of Repetition of Weathers of Various Degree of Favorability for Various Stages of Development of Poltavka Wheat
2. Points of Observation
3. Sprout - Seeding: 1-20 May
4. Seeding - Heading: 21 May-30 June
5. Voroshilovgrad
6. Penza
7. Yelabuga
8. Malyy Uzen'
9. Heading-Half Milk Ripeness: 21 June-5 July
10. Half Milk Ripeness-Milk Ripeness: 1-15 July
11. Milk Ripeness-Yellow Ripeness: 11-31 July
12. Categories of Favorability
13. Note: Combining of categories indicates the difficulty of their division

Table 7.

1. Relative moisture (in %)
2. Speed of wind (in m/sec)
3. Temperature of the air (in °C)

KEYS TO APPENDIXES

Key to Appendix I

1. Wind Characteristics
2. 1st letter of the code
3. Winds of constand direction
4. Winds of Varying direction
5. Direction of the wind: moderate, 1-3; brisk, 4-7; strong, 8-13; storm 14
6. Wind direction according to quarters: [same as in 5]
7. [illegible] m/sec)
8. The wind [illegible]
9. [illegible] [example: N [illegible] to E [illegible]]
10. Wind of sharply va[illegible] direction
11. Still: (0; quiet wind: [illegible]
12. Note: the gradations [illegible] the wind velocity are given for a weather vane in a low position. For a weather vane raised above surrounding objects, the velocity gradations will be: 2-4; 5-10; 11-18; 19 and higher. For a weather vane that is very high, they will be: [illegible]-6; 7-15; 16-26; 27 and higher.

KEY TO APPENDIX II

1. Coding of air temperature by Ye. Ye. [illegible]'s method
2. The graphs of "Air temperature" in the tables [illegible] observations T.M-1 serve as the [illegible] for the coding. The entire coding [illegible] is encompassed by four operations.
3. Operation I
4. Operation II
5. Operation III
6. Average Daily temperature of air (in °C)
7. Variation of average daily temperature of air (in °C) from the preceding 24 hours
8. Increase to
9. Lowering to
10. 5.3 and more
11. Daily amplitude of air temperature (in °C)

KEY TO APPENDIX II (continued)

1. Operation [illegible]
2. Average daily air temperature (in °C)

[illegible]

[illegible]

[illegible]

[illegible]

3. Operation II

[illegible]

[illegible]

4. [illegible]
5. [illegible]
10. [illegible] the average daily temperature [illegible] greater than [illegible] from the preceding day, one replaces the result of operation I by another letter or two [illegible] letters, as shown in the table. If the variation was greater than 10°, then still another proper code is written
11. Lowering to
12. 5.3 and more
13. Operation III
14. Daily amplitude of air temperature (in °C)
15. To determine the [illegible] of the main and supplementary [illegible] upon the daily amplitude (that is, the [illegible] between the [illegible] at 1300 (1 P. M.) and the [illegible] [illegible] there is no supplementary letter, but according to operation II, the letter is required, then repeat the main letter in the supplementary letter, already in another plan, as shown in the table

   C - lower-case letter

   [illegible] - capital letter

16. Operation IV: to note thow ("OTT") at the mean temperature 0.0° and lower, when the temperature was higher than 0.0° even in one of the periods of observations.

KEY TO APPENDIX III

1. Coding of Cloudiness, Relative Moisture (Humidity), and Precipitation According to Ye. Ye. Fedorov's Method

2. The entire coding is encompassed by 4 operations

3. Operation I

4. Operation II

[illegible] at night and in the daytime

[illegible] the daytime

[illegible]

[illegible]

10. Cloudiness in the daytime

11. [illegible] precipitation, or precipitation less than 0.6 mm

12. Up to mid day (π, a)

13. After midday (p)

14. Up to and after midday (n,a,p)

15. 1.4 and more [note: и более : "and more"]

16. The numbers (values of cloudiness) are replaced by vowels, as shown in the table. The cloudiness at night is calculated in the following manner:

a) for three periods of observations (21 hours + 07 hours): 2;

b) for four periods of observations [19 hour + 01 hour): 2 + 07 :2

[note: 01 hour means 1:00 A.M.]

Cloudiness in the daytime: the value of cloudiness at 1300 (1 P.M.)

17. Note: The letter "i" stands in those cases where at 0700 [7:00 A.M.] the cloudiness is less than 6, the letter "y" means the cloudiness is equal to or greater than 6 at 0700 [7:00 A.M.]

KEY

APPENDIX TO THE APPENDIX III

1. Coding of cloudiness relative humidity, and precipation accordance ... method. All processes of coding are encompassed by four operations

[illegible]

... the following manner:

6. ... symbol [Note: "знак" means "symbol"]

7. 80 and more [Note: "и более" means "and more".]

8. 0700 (or 7:00 A.M.) [Note: "ч." means "hour"]

9. Relative Humidity in %

10. C - lower-case letter

П - capital letter

11. To determine the plan of the main and supplementary letters in dependence upon the mean relative humidity. If there is no supplementary letter, but according to Operation IV such a letter is required, then repeat the main letter in the supplementary letter in the plan, as shown in the table.

KEY TO APPENDIX IV

1. Characteristics of Various Phenomena in the Atmosphere and of the State of the Earth's Surface
2. For nonfrozen surface
3. For frozen surface
4. [illegible]
5. Time of [illegible]
6. Hoarfrost (rime)
7. Wet
8. Dew
9. Dry
10. [illegible]
11. [illegible]
12. Hail
13. Strong snowstorm
14. Without the indicated phenomena
15. During a storm with strong rain (the quantity of precipitation, 10 mm and greater).
16. During a storm with rain (from 1 mm up to 10 mm)
17. During a storm without rain (less than 1 mm) and a faraway storm
18. Snow cover without designation of thickness:
19. Relatively uniform
20. Strongly uneven
21. Snow cover uniform
22. Of height (i.e. depth): /Note: высотой means "depth"/
23. Snow cover uneven:
24. Of depth
25. Note: Fog is designated thus: up to midday, by a line through the letter; up to and after midday, by two lines through the letter; whole day, by three lines through the letter. Showers without a storm (10 mm and more) are noted by the symbol 1 after the letter. Hail is denoted only during a storm by the symbol * after the letter

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